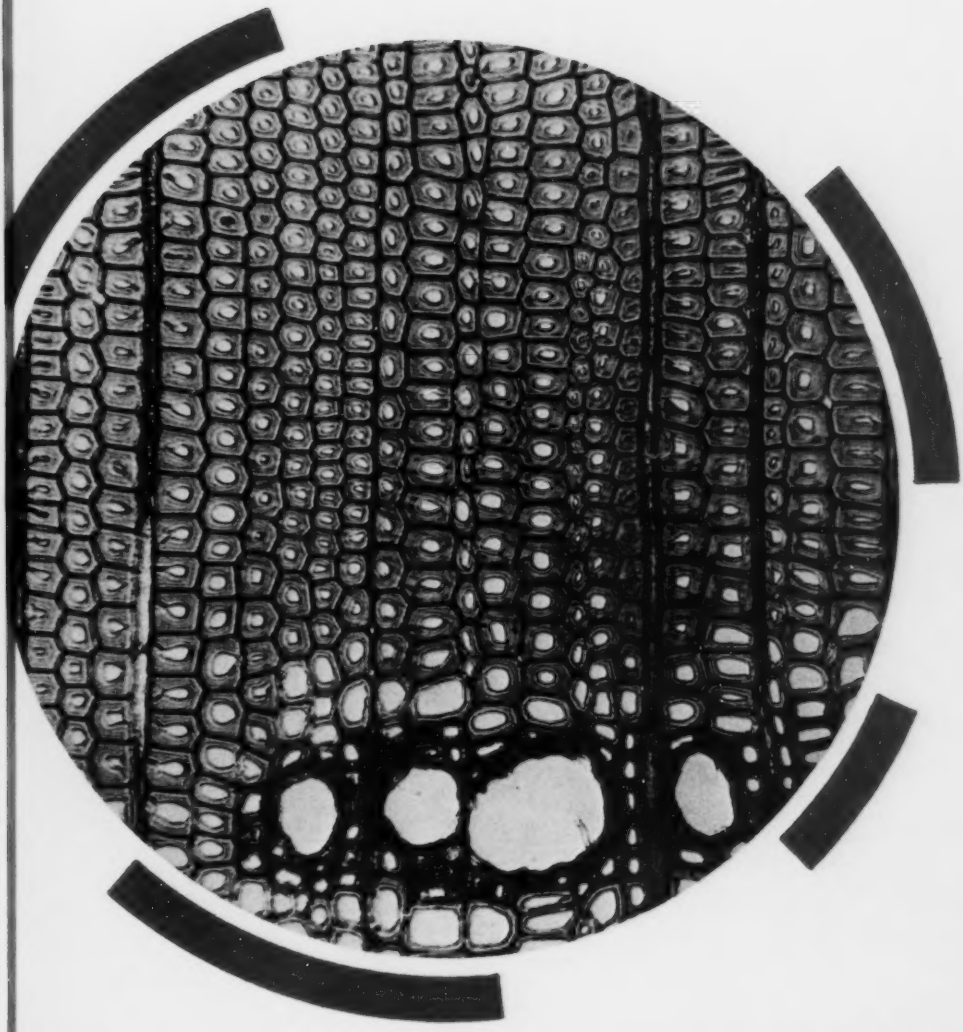
A Quarterly Journal of Research and Technical Progress

FOREST *Science*



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Volu

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Longevity of the oak wilt fungus in red oak lumber
George H. Englerth, John S. Boyce, Jr., Elmer R. Roth 2

Big game populations in the National Forests, 1921 to 1950
Homer L. Schantz 7

Effect of slash burning on some physical soil properties
Robert F. Tarrant 18

Maturity of Colorado spruce cones
W. H. Cram 26

Effect of defoliation on growth of longleaf pine seedlings
David Bruce 31

Viable seeds from the duff and soil of sugar pine forests
Clarence R. Quick 36

Effect of soaking position on treatability of pine fence posts
C. S. Walters, W. L. Meek 43

Prevention of damping-off of poplar seedlings
Keith R. Shea, J. E. Kuntz 54

Transmitted effect of allyl alcohol on growth of Monterey pine seedlings
S. A. Wilde, G. K. Voight, D. J. Persidsky 58

Windthrow around staggered settings in old-growth Douglas-fir
H. J. Gratkowski 60

German silvicultural systems
Stephen H. Spurr 75

REVIEWS: Soil physics 17, Forestry handbook 22

The cover design is a microphotograph of Douglas-fir in transverse section by Stephen B. Preston, University of Michigan.

Volume 2
March 1956
Number 1

Longevity of the Oak Wilt Fungus In Red Oak Lumber

BY
GEORGE H. ENGLERTH
JOHN S. BOYCE, JR.
ELMER R. ROTH

FEW TREE DISEASES have been as intensively investigated in the United States as oak wilt, caused by the fungus *Endoconidiophora fagacearum* Bretz. In a recent article, Hepting (1955) has summarized current knowledge about the disease.

However, little has been published concerning the longevity of the wilt fungus in boards sawed from infected trees (Spilker 1953, Spilker and Young 1955). It was the purpose of the present study to find out how long the wilt fungus could live in 1-inch lumber sawed from infected trees, when the boards were either (1) steamed, (2) kiln-dried, (3) bulk-piled, (4) sticker-piled, or (5) sprayed with sodium pentachlorophenate and sticker-piled.

Infected Oaks Used in Study

On September 15, 1954, 1 scarlet oak (*Quercus coccinea* Muenchh.), 3 black oaks (*Q. velutina* Lam.), and 8 southern red oaks (*Q. falcata* Michx.) that showed active wilt symptoms during the summer were felled in the vicinity of Greeneville, Tennessee. These 12 trees ranged in size from 10 to 20 inches d.b.h. with an average diameter of 14 inches. Since it is well known that mold and staining fungi soon invade dying and dead trees, only trees with a fresh, green cambium layer were used, in order to avoid interference from concomitant fungi in isolating for the oak wilt fungus.

Two-inch-thick disks were cut from the bottom and top of each of the 46 seven-foot logs cut from the felled trees. These disks were used for culturing and moisture determination. Isolations for the oak wilt fungus were made from wood samples taken from three different places on the circumference of each disk. At each place, samples were taken from the outer sapwood, at ½-inch sapwood depth, and at 1-inch sapwood depth.

The bark of all logs was sprayed with a mixture of 0.5 percent gamma isomer benzene hexachloride and 2 percent pentachlorophenol in No. 2 fuel oil in order to inhibit insect infestation and fungus contamination during storage. This treatment had no apparent effect on the wilt organism in the wood. The log ends were paraffined to reduce moisture loss through the exposed end grain, and to reduce end splitting and checking.

Test Logs Sawed Into Lumber

Fifteen of the test logs were cut into 1-inch lumber 2 days after felling; the remaining logs were piled in a sawmill yard and shaded from the sun. After 3 weeks, 15 of the piled logs were sawed, and after

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6 weeks the remaining 16 logs were sawed. These log-storage periods were used because in commercial practice logs are often held for 6 weeks or more before they can be sawed. The logs were evenly divided among the three sawing periods according to position in the tree, tree species, size, and individual tree.

At each respective sawing period the logs to be tested were quartersawed and yielded a total of about 100 boards, or 20 boards for each of the five treatments to be applied. The bark on all boards was removed by hand soon after cutting. All boards, except those steamed, were paraffined on the ends to prevent excessive drying. Cut surfaces on each board were paraffined each time a sample was taken. The purpose of this end treatment was to maintain a uniform rate of drying throughout the length of the board.

Treatments

One-fifth of the boards were sprayed with a solution of borax and sodium pentachlorophenate[1] at a rate of 10 pounds per 100 gallons of water and then sticker-piled; a fifth were sticker-piled green; a fifth were bulk-piled; a fifth were sticker-piled green until the average moisture content was about 30 percent and then kiln-dried; and the remaining fifth were steamed in sticker piles. The steaming treatment consisted of releasing live steam under 80 pounds nozzle pressure into a small, closed room for 30 minutes. Steaming of the third-sawing boards was omitted because the cooperating mill burned in the meantime. The wane edges of these boards were paraffined and the boards sticker-piled.

Cultures were made at 2-week intervals until the fungus could no longer be isolated from boards bulk-piled, sticker-piled, or chemically sprayed and sticker-piled. In each series of tests, isolations were attempted for at least two culture periods or 4 weeks after last obtaining positive oak wilt cultures, in order to make sure that the fungus was no longer active.

Blocks about 2 inches long, the depth of the sapwood and the thickness of the board, were cut from both ends of each board at each culturing period. The surfaces of the blocks were not sterilized except for the blocks taken from stickered boards 4 weeks after the first sawing. At this time the blocks were dipped in alcohol and flamed, but since this treatment sterilized about 90 percent of the isolation chips, this method was not used again. All blocks were split radially, and small chips were removed for planting on Barnett's culture medium.[2] Isolations were attempted from each block from the outer sapwood, ½ inch in from the cambium, and 1 inch in from the cambium.

All oak wilt cultures were verified microscopically after they were incubated from 5 to 10 days at laboratory temperatures. Moisture content determinations were made on samples adjacent to one of the culture blocks from each board at each culturing period.

Kiln-Drying and Steaming Killed Oak Wilt Fungus

Kiln-drying and steaming killed the oak wilt fungus in boards of the first and second sawings. These treatments were omitted for boards of the third sawing. The kiln schedules for boards of the first and second sawing are shown in Table 1.

Viability of the Fungus in Wood

Fifty-six percent of the cultures attempted from the outer sapwood layers of the freshly cut logs yielded the oak wilt fungus (Table 2). The fungus was isolated from 41 of the 46 logs. At this first stage, the fungus was not found at the ½-inch and 1-inch depths in the sapwood. However,

[1]Permatox 10-S, Chapman Chemical Company, Memphis, Tenn.

[2]Barnett, H. L. Isolation and identification of the oak wilt fungus. W. Va. Univ. Bull. 359 T. April 1953.

TABLE 1. Kiln schedules for first and second sawing periods.

Period (hours)	Temperature: Dry bulb (degrees F.)	Temperature: Wet bulb (degrees F.)	Equilibrium moisture content (percent)
	First Sawing		
24	120	106	10
18	140	100	4
24	160	110	3
	Second Sawing		
19	130	105	7
95	140	100	4
8	160	120	4
36	180	130	3

logs that were stored 6 weeks yielded the fungus at these depths. No attempts were made to isolate the fungus from sapwood deeper than 1 inch.

The oak wilt fungus was viable in some bulk-piled boards 18 weeks after the lumber had been cut from logs stored 6 weeks, a total of 24 weeks after the trees had been cut.

Some boards sprayed with sodium pentachlorophenate and borax yielded the oak wilt fungus 10, 8, and 12 weeks after the first, second, and third sawings, respectively. tively.

Critical Moisture Content

The sapwood moisture contents of boards yielding the oak wilt fungus ranged from 20 to 57 percent of ovendry weight (Table 3). Thirty-three attempts to isolate the oak wilt fungus from previously infected boards failed after the boards were dried to a moisture content of less than 20 percent. Of successful oak wilt cultures taken from a total of 56 boards, about one-third were made from boards with sapwood moisture contents between 20 and 30 percent.

Penetration During Seasoning

The wilt fungus penetrated at least 1 inch into the sapwood during air seasoning. In 14 days, the fungus was recovered at the ½-inch depth in stickered boards of the first sawing, and at 1 inch in 28 days. for chemically sprayed boards, the fungus was isolated from a sapwood depth of 1 inch in 14 days.

Contamination by Other Fungi

The percentage of isolations yielding fungi other than the oak wilt fungus increased as the log-storage period increased. Only 3 percent of the cultures from the outer sapwood were contaminated initially, but 40 and 49 percent were contaminated after

TABLE 2. Isolation of the oak wilt fungus from logs, 0, 3, and 6 weeks after tree felling.

Log storage period (weeks)	Sapwood layer	Culture results: Total chips cultured (number)	Oak wilt fungus isolated (percent)	No organisms isolated (percent)	Contaminated by other fungi (percent)
0	Outer	157	56	41	3
	½ inch	157	0	100	0
	1 inch	130	0	100	0
3	Outer	45	9	51	40
	½ inch	45	0	73	27
	1 inch	45	0	80	20
6	Outer	45	11	40	49
	½ inch	45	2	49	49
	1 inch	39	5	59	36

TABLE 3. Isolations of the oak wilt fungus from boards.

Treatment	Seasoning time	Total boards studied	Boards yielding fungus	Sapwood moisture content of infected boards	Isloates at sapwood depths of—		
					⅛ inch	½ inch	1 inch
	Weeks	*Number*	*Number*	*Percent*	*Number*	*Number*	*Number*
			First Sawing				
Sticker-piled	2	21	1	43	0	1	0
	4	21	1	26	0	0	1
Sprayed and sticker-piled	2	21	5	44–56	3	1	1
	4	21	1	34	1	0	0
	8	21	2	22, 27	1	1	0
	10	21	1	22	0	1	0
			Second Sawing				
Sticker-piled	2	19	2	34, 39	2	0	0
Sprayed and sticker-piled	2	18	2	31, 38	1	2	2
	4	18	3	21–33	1	1	2
	8	18	1	24	1	0	0
Bulk-piled	2	19	1	47	1	0	0
	4	19	1	51	1	1	0
	6	19	1	51	1	0	0
	8	19	2	32, 51	2	0	0
	10	19	2	35, 46	1	1	0
			Third Sawing				
Sticker-piled	2	24	1	39	1	0	0
	4	24	4	29–39	3	1	1
	6	24	1	29	1	0	0
	10	24	1	25	0	1	0
	14	24	1	21	1	0	0
Sprayed and sticker-piled	2	23	1	40	1	0	1
	10	23	1	27	1	0	0
	12	23	1	22	1	0	0
Bulk-piled	2	23	2	40, 46	2	1	1
	4	23	2	50, 53	2	1	0
	10	21	3	30–38	2	1	0
	12	22	1	33	1	0	0
	16	22	2	31, 35	2	0	0
	18	17	1	25	0	1	0
Sticker-piled (back edges waxed)	2	23	2	42, 57	2	0	0
	6	23	1	31	1	0	0
	12	23	1	32	1	0	0
	14	22	3	20–26	3	0	0
	16	22	1	21	1	0	0

3 and 6 weeks. Likewise, cultures from ½-inch and 1-inch sapwood depths were sterile initially, but 20 to 49 percent were contaminated after 3 and 6 weeks log storage.

The sapwood of freshly cut lumber is invaded by stain and mold fungi in a day or two during the summer months unless protected by an antistain chemical. Ninty-one percent of the isolations from the bulk-piled boards of the first sawing period were contaminated after 2 weeks and 86 percent contaminated after 4 weeks. The high percentage of these other fungi practically eliminated the possibility of isolating the wilt fungus from contaminated boards. Fifty-one percent of the isolations from the stickered boards of the first sawing were contaminated at 2 weeks.

The boards sprayed with sodium pentachlorophenate yielded less than 10 percent contaminated chips at the first sawing, and 28 and 80 percent after 3 and 6 weeks, respectively.

Temperature Relations

Daily air temperatures between 70°F. and 90°F. were common during the first 4 weeks of seasoning. At the end of these 4 weeks the fungus was still viable in some stickered boards of the first sawing.

At no time was the fungus isolated from boards below 20 percent in moisture content. The lumber dried more slowly at the lower daily temperatures of 40° to 60°F. that occurred during November and December, and the moisture contents of the boards remained greater than 20 percent for a longer period of time in the cooler weather.

Relevant Experiments

The results presented here differ from those reported by Spilker (1953). He failed to isolate *Endoconidiophora fagacearum* from oak lumber or sawdust either at the time the diseased trees were sawed into lumber or 3 weeks later. Although he isolated the fungus from slabs at the time of sawing, he did not recover it after 3 weeks. In a later study, Spilker and Young (1955) isolated the wilt fungus from blocks stored for 12 weeks at 5° and 20°C., but they did not isolate the fungus after 5 weeks of storage at 25° and 27.5° C. It is noteworthy that they isolated the fungus from sapwood with a moisture content as low as 14.5 percent.

Summary

The longevity of the oak wilt fungus in red oak lumber sawed from infected trees was investigated. The fungus was isolated from boards with the bark removed that had been air-seasoned for as long as 16 weeks in one instance and bulk-piled for 18 weeks in another. Considering a log-storage period of 6 weeks from the time of cutting, the fungus was still viable after 22 weeks and 24 weeks respectively in air-seasoned and bulk-piled boards.

The fungus was not isolated from sapwood that contained less than 20 percent moisture.

Spraying the surface of boards with sodium pentachlorophenate did not kill the fungus in the wood, but both steaming them for ½ hour and kiln-drying did.

Although the fungus occurred only in the outer sapwood of the living trees used in this study, it penetrated to a sapwood depth of at least 1 inch in boards within 2 weeks after sawing and in logs after 6 weeks storage period.

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Hepting, G. H. 1955. The current status of oak wilt in the United States. For. Science 1: 95-103.

Spilker, O. W. 1953. The longevity of *Endoconidiophora fagacearum* in lumber and other wood products cut from diseased trees. Phytopathology 43: 485.

————and Young, H. C. 1955. Longevity of *Endoconidiophora fagacearum* in lumber. Plant Dis. Reptr. 39: 429-432.

Big Game Populations in the National Forests, 1921 to 1950

BY
HOMER L. SCHANTZ

THE NATIONAL FORESTS, which now have a gross acreage of over 220,000,000 acres of which 180,000,000 acres are federal lands, were initiated when President Benjamin Harrison established "The Yellowstone Park Timberland Reserve" in 1891. Later 15 Forest Reserves totaling more than 13,000,000 acres were established by President Harrison. In 1905 President Theodore Roosevelt transferred the Forest Reserves to the Department of Agriculture and designated them "National Forests." In 1908 the Forest Service was established.

Before the arrival of the Europeans, the big game on these lands were subjected to hunting by Indians, and were preyed upon by such large predators as grizzly bears, timber wolves, cougars and coyotes. The European pioneers placed an additional heavy drain on game and furbearers for food and clothing. With the advance of agriculture, big game was pushed back from much of the more productive to the less productive and less accessible land. It is this land which constitutes much of the National Forests. This large area is not cultivated but held as wild land on which big game animals live naturally.

It is probable that big game had reached its lowest level in the United States at about the time the Forest Service was established. Naturally one of the early activities of forest service men had to do with big game. The bison was threatened with extinction and the New York Zoological Society supplied bison to stock the Wichita National Forest in Oklahoma. The Grand Canyon Forest Reserve established in 1893 was in 1906 made a Game Reserve and later the northern portion became the Kaibab National Game Reserve. By 1924 this area had become over-populated by deer and in the winter of 1924 and 1925 an estimated winter starvation amounted to from 10,000 to 12,000. Strong opposition to hunter harvest prevented proper control of the size of the herds. About 1173 deer were trapped and some of them moved to other forests, a few were killed by hunters, but all in all winter starvation following the nearly total loss of the browse plants within reach of the deer resulted in 1931-1932 in a deer loss so great that what was regarded as an ideal range for from 50,000 to 60,000 deer could not support 15,000 without further winter starvation. Not until about 1946 was the range somewhat recovered when an increasing deer herd again destroyed all forage within its reach. In other words the range had partly recovered in 15 years only to be again badly damaged by too many deer.

The Pisgah National Game Preserve authorized in 1916 had by 1930 become so

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overpopulated by deer that the seedlings, bushes and young trees valuable as deer browse were being eliminated. Between 1926 and 1940, 1519 deer were captured and moved to other forests in other states as follows: Alabama 118, Arkansas 61, Florida 20, Georgia 219, Indiana 10, Kentucky 10, Mississippi 41, North Carolina 199, South Carolina 181, Tennessee 142, Virginia 188, and West Virginia 134. Much of the present deer crop of these states is due to the establishment of the Pisgah National Game Preserve.

Predator control was started on the National Forests in 1908 and continued until 1915 when it was transferred to the Biological Survey. During the period 1908 to 1915, 1300 wolves, 1400 bears, 600 cougars, 22,000 coyotes, 530 lynx and 3700 bobcats were taken on these lands. Forest service officers also urged the enactment of better state game laws and aided in the enforcement of those on the statutes. In 1912 and 1913, 266 elk were planted on the National Forests of Oklahoma, Oregon, Wyoming, Colorado, Utah and Arizona. The Forest Service in cooperation with the Biological Survey aided by State and other organizations moved the elk from the Yellowstone herd to areas from which elk had been extirpated. From these plantings have come many of the large elk herds of today.

Estimates of the big game populations by the Forest Service began in 1913 but it was not made service-wide until 1921. The estimates made by the rangers, the men on the ground, were assembled by the Forest Supervisor or a specially-assigned wildlife man and forwarded to the regional office. These were assembled in the Washington office and the record for each forest mimeographed or photostated for distribution. These summaries showing each forest and much additional material were published for the years indicated as follows:

1936 & 1937 Hearings Before the Select Committee on Conservation of Wildlife Resources 75th Congress, 3rd Session: 133-186, 1938.

1940 as above 77th Congress, 1st Session. 1-113, 1942.

1942 as above 78th Congress, 1st Session: 196-319, 1944.

1943 as above 78th Congress, 2nd Session: 119-218, 1945.

1944 as above 79th Congress, 2nd Session: 132-215, 1946.

1947 as above 80th Congress, 2nd Session: 103-217, 1948.

1937 & 1938 Report of the Special Committee on the Conservation of Wildlife Resources Pursuant to Senate Resolution 246, 76th Congress, 3rd Session, Senate Report No. 1203; 247-346, 1940.

1948 Hearings, Subcommittee to Investigate Wildlife Conservation, Committee on Expenditures in the Executive Departments United States Senate, 81st Congress, 1st Session: 181-231, 1949.

1949, as above 81st Congress, 2nd Session: 97-126, 1950.

1950, as above 82nd Congress, 1st Session: 191-221, 1951.

No one should be misled by assuming that the records are more accurate than they are. They are summations of many estimates and are sometimes supported by careful counts, and estimates by men who have spent many hours and days with the herds in their summer range, on their migrations, and on their winter range. They extend over a period of 30 years and cover roughly one acre in ten in the United States. The records have been carefully studied and marked departures adjusted when they were due to omissions of a record for that year or where unusually high records have been found in subsequent estimates to have been unjustifiable. They give as true a picture as the writer is able to present from the data at hand.

Big Game Animals

The estimates presented in Table 1 are totals for deer, elk, black bear, antelope, mountain goat, moose, bighorn sheep, grizzly and Alaska brown bear, peccary and wild boar. The last two have not been given separate consideration. These estimates show (Fig. 1.) that the total of big

game had increased rather rapidly from 1921 to 1942 or for the first 22 years. If one applies the compound interest formula $y = ab^x$ in which y = the number of animals, a = the number of animals when x = 0 or in this case in 1920 and b = 1 plus the rate of increase, the rate of increase from 1921 to 1942 was 7.4 percent compound interest. The departures in 1933 and 1934 will be discussed under deer. If this rate of increase is indicative of what was happening between 1908 and 1920 the big game population in 1908 would have been about 230,000.

In 1943 and 1944 there was a marked falling off and from 1944 to 1950 the increase rate was only about 3 percent. This break in the rate of increase is easily accounted for. The winter 1941-1942 was an open winter and there were many areas occupied by excessively large herds of elk or of deer which so heavily over-browsed the plants to the extent that they produced little or no feed and many of them died. The herds in 1942-1943 suffered an unusually heavy winter loss by starvation. The break shown in 1943 was caused more by winter starvation in 1942-1943 than by hunter take although the hunter take in 1942 was 8.9 percent for deer and 16 percent for elk, the highest recorded up to that time.[1]

These are summations of many areas and of several kinds of game animals and while the totals tend to level off as time goes on the individual herds increase rapidly to numbers far in excess of the sustained

[1]See reference above for 1942, especially pages 266 to 292.

TABLE 1. Estimates of big game, deer, and elk on the National Forests, 1921 to 1950.

	All Big Game			Deer			Elk		
		Hunter Take			Hunter Take			Hunter Take	
Year	Number	Number	Percent	Number	Number	Percent	Number	Number	Percent
1921	585,000			460,000			43,900		
1922	624,000			474,000			45,300		
1923	680,000			536,000			48,900		
1924	693,000			558,000			53,000		
1925	772,000			610,000			61,100		
1926	848,000			678,000			68,600		
1927	920,000	45,100	4.9	746,000	38,000	5.1	78,500	4,000	5.1
1928	978,000	49,200	5.0	799,000	43,000	5.4	80,700	2,700	3.3
1929	1,051,000	59,600	5.7	866,000	50,000	5.8	87,500	5,100	5.8
1930	1,137,000	66,900	5.9	932,000	58,000	6.2	93,300	4,400	4.8
1931	1,243,000	82,600	6.6	1,030,000	73,000	7.1	101,400	6,800	6.7
1932	1,243,000	72,900	5.9	1,043,000	62,000	5.9	108,500	7,500	6.9
1933	1,239,000	68,700	5.5	1,034,000	61,000	5.9	118,100	7,100	6.0
1934	1,371,000	91,400	6.7	1,154,000	82,000	7.1	123,400	8,900	7.2
1935	1,629,000	109,200	6.7	1,404,000	93,000	6.6	132,500	15,500	11.5
1936	1,805,000	124,700	6.9	1,459,000	113,000	7.8	138,800	10,800	7.8
1937	1,860,000	119,900	6.4	1,605,000	103,000	6.4	149,000	13,000	8.7
1938	2,009,000	169,500	8.5	1,731,000	146,000	8.4	158,900	18,900	11.0
1939	2,110,000	180,400	8.5	1,849,000	162,000	8.8	159,500	13,500	8.5
1940	2,300,000	200,200	8.7	1,987,000	176,000	8.9	174,400	18,400	10.6
1941	2,434,000	216,300	8.8	2,054,000	136,000	6.6	180,000	20,000	11.1
1942	2,562,000	236,400	9.2	2,213,000	198,000	8.9	196,500	31,500	16.0
1943	2,493,000	227,900	9.1	2,133,000	193,000	9.0	189,000	26,000	13.8
1944	2,468,000	185,000	7.5	2,140,000	158,000	7.4	165,000	17,000	10.3
1945	2,525,000	212,600	8.4	2,176,000	181,000	8.3	182,000	22,000	12.1
1946	2,612,000	264,700	10.1	2,255,000	222,000	9.8	191,000	32,000	16.8
1947	2,664,000	274,700	10.3	2,302,000	233,000	10.1	195,000	32,000	16.4
1948	2,743,000	322,900	11.7	2,358,000	238,000	10.1	216,000	30,000	13.9
1949	2,790,000	317,100	11.4	2,400,000	270,000	11.3	229,000	37,000	16.2
1950	2,957,000	355,000	12.0	2,534,000	304,000	12.0	239,000	41,000	17.2
Average Hunter Take			7.9			7.8			10.4

carrying capacity of the range and of the land and then drop within a year or two to a number far below the optimum. For deer and elk and for all herbivora wild or domestic the first mouthful the animal takes reduces his food reserve by that amount. In other words he uses the capital, not the interest. The food manufacturing plant is eaten. If this use is not too severe the process can be continued for many years, but when once the consumption is in excess of the production the decline is rapid and when consumption is stopped the recovery is slow.

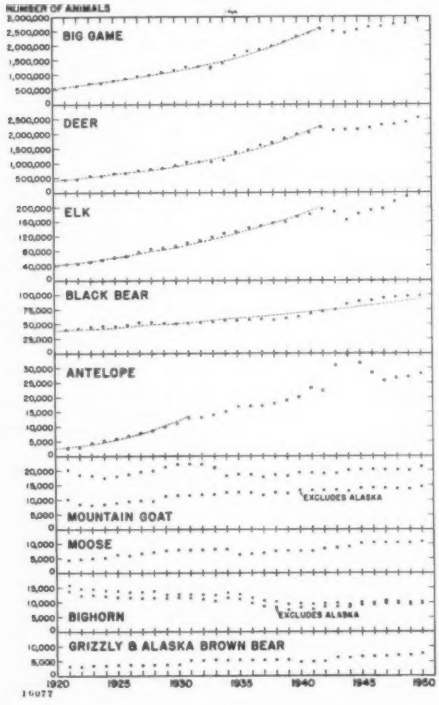

FIGURE 1. *Big game populations for 1921 to 1950. The actual estimates are shown as dots. Estimated values as x. The totals include Alaska, but for mountain goat and bighorn, the lower graph is for the states only. The compound-interest values shown by the dotted line are for big game 7.2 percent, for deer 8.0, for elk 7.5, for black bear 3.0 and for antelope 17.0 percent.*

While food is abundant the rate of increase seems to follow the compound interest graph until the demand for food exceeds the supply when the population drops suddenly to a quarter or less of the maximum. There is no indication of a gradual slowing down of the rate of increase to establish the maximum number that can be produced or maintained as would be indicated by the application of the growth, logistic or sigmoid graph.

During the period 1921 to 1926 there was some hunter take but the figures are not available to the writer and were in all probability not sufficient to greatly influence the results. In the western states practically no protection was given big game prior to the beginning of this century. According to Palmer[2] in 1900 only North and South Dakota and Wyoming required out of state licenses and North Dakota and Wyoming resident licenses of one dollar or less. By 1904 Nebraska, Montana, Colorado, Utah, Idaho and Washington had also required non-resident licenses and South Dakota, Nebraska, Colorado, Idaho and Washington had also required a resident license of one dollar or less. Non-resident licenses ranged from one to fifty dollars. For many years these laws were difficult to enforce.

The hunter take of total big game is given in column 2 and in percent of the total size of the herd in column 3 of Table 1. The average for the period 1927 to 1942 was 6.9 percent or less than the rate of increase. This means that the hunter take was about half enough to control the size of the herds. During the period 1943 to 1950 the average hunter take was 9.8 percent but still the population advanced at the rate of 3.1 percent.

[2]Palmer, T. S. 1904. Hunting licenses, their history, objects and limitations. U. S. Dept. Agric., Biol. Surv. Bull. 19.

Deer

About 86 percent of the big game animals on the National Forests are deer. Of the deer, about 61 percent are mule deer, 28 percent white-tail, and 11 percent black-tail. According to the reports of the Fish and Wildlife Service (Wildlife Leaflet 342, Oct. 1953.) about a third of the total number of deer in the United States are on the National Forests. Deer are the most numerous and the most sought after of all big game animals.

The rate of increase from 1921 to 1942 (Table 1, Fig. 1.) was 8 percent. A slight break seemingly occurred in 1932, 1933 and 1934. An examination of the records shows most of the falling off of the rate of increase was in California and Oregon, and it seems to the writer to have been due indirectly to a slight increase in hunter take in 1931. Almost without exception an increase in hunter take was followed by general reports that the herds had been too greatly reduced and that there were fewer deer than estimated. Almost without exception the reports from the forests indicated that too many deer had been harvested and as a consequence the estimates for the succeeding year or two were lower than would otherwise have been the case. The fact that the estimates in 1935 and the following years were back on the 8 percent graph and continued on it until 1942 would indicate that the departures were probably due to conservative estimates. There was however a real break on the rate of increase in the forests of Arizona and New Mexico in 1934.

A real break came in 1943 and none of the succeeding estimates even approximate the previous trend. An increase of 2.5 percent continued to 1950. As early as 1928, many deer herds had increased beyond the capacity of the range to support them, and by 1933 overstocked areas became increasingly abundant. This condition is not reflected in increase hunter kill until about five years later. Still the increase in hunter take did not affect the rate of increase until after 1941. As a rule the initial evidence of damage to the range due to overstocking has had little effect in causing an increase in crop harvest, and even after a heavy starvation loss there is a tendency to reduce the hunter take on the assumption that the starvation death has sufficiently reduced the herd size.

On the Allegheny National Forest with 60,000 deer in 1938, 24,000 does were killed by hunters and the herd was estimated at 40,000 after the hunt. In 1943 when the herd was estimated at 12,000, many died of winter starvation.

The hunter kill from 1927 to 1942 never exceeded 8.9 percent of the herd, and averaged only 6.9 percent. Up to the time the damage became apparent on many forests in 1933 the hunter take had never exceeded 7.1 percent and averaged only 5.9 percent. Only during the period 1943 to 1950 when the rate of increase was about 2.5 percent did the hunter take equal 12 percent and only averaged 9.8 percent. It must be evident to all who manage deer ranges that a better distribution of hunter take is the most feasible means of securing a better distribution of deer and of securing the highest sustained yield, avoiding overpopulation and the resultant damage to the forage cover. In other words a properly distributed and adequate harvest by hunters will not only insure the maintenance of the breeding herds, but will also protect the deer range against destructive use of the forage cover. But the harvest cannot be left to chance, to the demands of the sportsmen or other interested parties or to state-wide regulations, but must be adjusted by trained game technicians uninfluenced by pressure groups and who can limit heavy take to overstocked herds and protect or lessen the take on understocked herds. The success of the program of restoration should be measured in high sustained yield, and not in numbers of animals only, for in the end there must be a leveling off and a balance between the number of animals and the ability of the land to

support them on a sustained yield basis.

If one assumes that a deer doe will have one fawn at two years and two each year thereafter and will live ten years, and that the first fawn is a doe and that the sexes are equal thereafter, the productive rate would be nearly 55 percent. It would seem likely that under favorable conditions deer herds would double every two years if the sexes are equal and much more rapidly if only bucks have been shot. In other words "deer eruptions" should be regarded as only normal under favorable conditions. For those who manage deer herds, harvest should be the only reasonable means of controlling deer populations and this can only be done by taking female deer. The buck law means that half of the deer crop must die in the woods.

In very general terms, the annual deer herd increase has been spent about as follows: one-fourth has been taken by hunters, one-fourth has been left on the range and at least one-half has been lost to starvation, disease and predators. The field is open for great advancement in the use and improvement of this wildlife resource, and many of our technical men have the factual information to bring this about if they are given the authority and opportunity to apply their knowledge to the solution of the many problems in this field.

The buck law, valuable in building up herds, is equally effective in destroying them when once they have reached the carrying capacity of the range. It is also terribly wasteful of both deer and forage, and has been oversold among sportsmen and the general public.

Elk

Next to deer, elk are the most numerous big game animals on the National Forests. They are about one-tenth as numerous as deer. Elk were reduced to low numbers by 1908, but many plantings were made in 1912 and 1913 by the Biological Survey and the Forest Service as listed above. From these plantings many of the present herds have developed. Large numbers are now found in the forests in Idaho, Colorado, Montana, Oregon and Washington.

The estimated population from 1921 to 1950 are given in Table 1 and shown in Figure 1. From 1921 to 1942, the rate of increase has been 7.5 percent. However, the estimates from 1938 to 1941 have fallen below this rate. A decided break came in 1943 and 1944. After this period the increase from 1944 to 1950 was at the rate of 6.7 percent. The cause of this reduction in rate of increase following 1938 and especially the break in 1943 and 1944 was partly due to hunter take, but largely due to winter starvation due to winter ranges badly damaged by excessive numbers of elk.[3]

If we assume that a cow elk will have a calf at three years and that the sexes are equal and that they live eleven years, the rate of increase would be about 27 percent. This is less than half as fast as deer. It is also probable that predation on elk is much less than on deer, since such large predators as grizzly and timber wolves are no longer important factors in their control.

The hunter take of elk has been much higher in proportion to total numbers than it has been for deer. The average for the period 1927 to 1950 was 7.8 percent for deer and 10.4 percent for elk. Not until 1948 did the hunter take of deer exceed 10 percent but as early as 1935, the hunter take of elk was 11.5 percent. For the whole period the hunter take for each eight-year period was as follows:

	1927-1934	1935-1942	1943-1950
	percent	percent	percent
Deer	6.1	8.0	9.8
Elk	5.7	10.6	14.6

Even during the last five years, the hunter take of deer was only 10.7 percent while the hunter take of elk was 16.1 percent. The take of elk could probably be maintained at 17 percent allowing about 10 percent to be lost by natural causes other than hunting. The hunter take of deer

[3](See reference to Hearings above under 1942, especially pages 266 to 292.)

could safely be increased to double the number or one-fourth of the herd. We have managed our elk much better than our deer. In both cases, however, it was not the hunter that controlled the numbers as much as starvation, disease and predators. Good game management could lower the loss in each of these cases.

Black Bear

Black bear are almost as widely distributed on National Forests as are deer and are next to elk in total numbers. The estimates from 1921 to 1950 are given in Table 2 and shown in Figure 1. The estimates of bear on the forests were not begun until 1923. The values for the first two years have been estimated and are shown in Figure 1 by an x. The rate of increase from 1921 to 1942 was 2.3 percent and after that period a little more rapid. On the whole the increase has been between 2 and 3 percent. During the last seven years, the increase has been a little more rapid notwith-standing the hunter take of 8.4 percent. Black bear are becoming increasingly important as game animals and less generally regarded as predators.

Antelope

The open plains, the natural home of the antelope, have been so fully occupied by agriculture that antelope have often moved up to higher and less accessible land, much of which is in the National Forests. They increased rapidly from 1921 to 1931 at a rate of about 17 percent. If we ignore the high estimates from 1943 to 1946, they advanced for the whole period 1921 to 1950 at the rate of 7.8 percent, which is a higher rate than for any other big game animal. The estimates for 1943 to 1946 are exceedingly variable. This may be due to migrations of herds or to errors in the estimates. They do not greatly affect the general picture.

Mountain Goat

Except for trans-plants in South Dakota, Colorado and Oregon these animals are found only in their natural habitat in Alaska, Washington, Idaho and Montana. A thriving colony is found in the Black Hills in South Dakota, but this is the only large herd outside of their natural area.

In Table 2 and in Figure 1 the totals are given and the values for the United States only. The values for 1921 and 1922 for Alaska are estimated and the Alaska values are responsible for the drop in estimates from 1932 to 1934. On the whole the totals show almost no increase although there is an increase of 1.2 percent from 1934 to 1950 for the totals. If only the estimates for the states are considered as shown in the lower graph the increase is about 1.6 percent for the whole period. The hunter take for the last seven years has averaged only 1.4 percent.

Moose

The rate of increase for the period 1921 to 1934 was 4.8 percent. However the estimates in Minnesota were reduced about 1300 in 1935 and were also lowered in Montana, the total drop being about 1900 animals. The increase from 1935 to 1950 was at the rate of 3.5 percent and for the whole period at the rate of 2.4 percent.

Bighorn

Bighorn so heavily hunted for meat in the earlier days are the only big game animals that have decreased in numbers on the National Forests since 1921. The estimates for totals and for the United States only are given in Table 2 and shown in Figure 1. The values marked in Figure 1 with an x are estimated. The Alaska figures for the years 1923 to 1925 were so low that they were discarded. The Alaska figures were lowered again in 1929. It is doubtful if the early estimates can be regarded as factual enough to be used to show the rate of decline. If the total figures are accepted, however, the rate of decline amounts to 1.1 percent. The decrease was somewhat greater from 1921 to 1939 after which date there has been a slight increase. If only the estimates for the states are considered, the decrease was 2.4 percent from

TABLE 2. Estimates of the numbers of black bear, antelope, mountain goat, moose, bighorn and grizzly and Alaska brown bear on National Forests, 1921 to 1950.

Year	Black bear	Antelope	Mountain goat		Moose	Bighorn		Grizzly and Alaska brown bear
			Total	U.S. Only	Total	Total	U.S. Only	
1921	42,000	2,400	20,000	10,000	4,200	15,800	13,800	3,200
1922	43,000	3,000	18,400	8,400	4,900	14,300	12,300	3,300
1923	44,000	4,600	18,100	8,100	5,000	14,600	12,600	3,300
1924	45,000	5,100	17,200	8,200	5,100	14,000	12,000	3,400
1925	46,000	5,900	17,900	8,900	6,100	13,700	11,700	3,400
1926	48,000	6,900	18,400	9,400	5,700	13,300	11,300	3,400
1927	51,000	7,700	19,300	9,800	6,400	13,200	11,200	3,400
1928	52,000	8,500	19,300	9,300	7,000	13,800	11,600	3,500
1929	51,000	10,000	21,000	11,100	7,500	12,300	11,300	3,500
1930	50,000	11,000	21,900	11,600	7,800	12,500	11,500	3,700
1931	51,000	13,000	22,300	11,300	7,800	12,600	11,100	3,800
1932	52,000	13,000	21,700	11,700	7,900	12,500	11,000	5,200
1933	56,000	14,000	21,200	11,900	8,100	12,200	10,600	5,200
1934	55,000	15,000	18,000	12,700	8,100	13,100	11,600	5,200
1935	55,000	17,000	18,500	12,600	6,200	12,900	11,300	5,300
1936	58,000	17,000	18,400	12,600	6,500	11,400	9,800	5,200
1937	59,000	17,000	17,600	11,700	6,800	10,400	8,800	5,200
1938	58,000	18,000	18,300	12,400	7,300	10,100	8,400	5,200
1939	59,000	19,000	18,000	12,200	7,300	9,200	7,600	5,200
1940	63,000	20,000	19,000	13,300	7,500	9,600	8,100	4,800
1941	67,000	23,300	19,000	13,200	7,400	9,200	7,700	4,900
1942	72,000	22,300	19,000	13,200	8,100	9,600	8,500	5,000
1943	75,000	31,000	19,000	13,300	8,400	9,800	8,700	6,100
1944	84,500	34,800	19,000	12,900	8,900	9,000	8,200	6,300
1945	88,700	31,900	20,000	13,900	10,000	9,900	9,000	6,400
1946	91,500	28,300	20,300	14,000	10,300	9,600	9,100	6,300
1947	94,000	25,600	20,300	14,000	10,300	10,000	9,500	6,500
1948	95,500	26,400	20,200	13,700	10,100	10,400	9,900	6,900
1949	97,100	26,900	20,300	13,700	10,200	9,800	9,300	6,600
1950	97,900	27,900	21,000	14,400	10,400	10,000	9,500	7,100

1921 to 1939 and from 1939 to 1950 there was an increase of 2.2 percent. In general terms they seem to be staging a slight comeback in the states but are losing ground in Alaska.

Grizzly and Alaska brown bear

The estimates for Grizzly and Alaska Brown Bear show a very unequal but a general increase of about 3.0 percent. If the Alaska estimates are eliminated, the estimates for the states proper vary between 660 and 950 and show a decrease of 0.2 percent. It is doubtful if under present conditions Grizzly on the National Forests of the different states can be maintained except possibly on the larger and more remote wilderness areas.

General Considerations

To compare briefly the numbers of big game animals on the National Forests and their rates of increase or decrease, two methods are used. In Table 3 the 1950 estimates are compared with the computed values for 1920. In Table 4 the average

TABLE 3. A comparison of numbers recorded for 1950 with the estimated number in 1920.

Animal	Total number in 1950 Actual	Percentage	Estimated 1920	1950 1920	Annual rate of increase percentage
Bighorn	10,000	0.3	15,800	0.63	—1.5
U.S. only	9,500	—	13,800	0.69	—1.3
Mt. Goat	21,000	0.7	20,000	1.05	0.1
U.S. only	14,400	—	8,000	1.44	1.9
Grizzly and Alaska brown bear	7,100	0.2	3,100	2.29	2.8
Moose	10,400	0.4	4,000	2.60	3.2
Black bear	97,900	3.3	37,900	2.58	3.2
Big game	2,957,000	100.0	543,300	5.44	5.8
Elk	239,000	8.1	43,100	5.55	5.9
Deer	2,534,000	85.7	422,600	6.00	6.1
Antelope	27,900	0.9	2,465	11.4	8.4

estimated number for the last five years 1946 to 1950 are compared with the first five years 1921 to 1925.

As shown in Table 3, Bighorn have decreased 1.5 percent per annum or, if the Alaska figures are eliminated, 1.3 per annum. Mountain Goat has increased only 0.1 percent, and if the Alaska figures are eliminated, they have increased 1.9 percent. Grizzly and Alaska Brown Bear have increased 3.0 percent, Moose 3.2 percent and black bear 3.2 percent; elk increased 5.9 percent; deer 6.1 percent; and antelope 8.4 percent.

In the second column of Table 3 the relative present number is shown in percent of the total of all big game. Deer constitute 85.7 percent of the total, elk 8.1 percent or together 93.8 percent. Of the others black bear number half of the remainder or 3.3 percent.

Antelope were 11.4 times as numerous in 1950 as in 1920, deer 6 times, elk 5.5 times, big game 5.4 times, black bear 2.6 times, moose 2.6 times, and grizzly and Alaska brown bear 2.3 times. Mountain goats have about held their own but bighorn have been reduced by about one third.

Since this comparison places too much emphasis on the first and the last estimate, Table 4 uses instead the averages of the first five and the last five years. The differences in the two tables are not very great, but the increase should be a little less in Table 4 since a thirty-year period is shown in Table 3 and a twenty-five-year period in Table 4.

The rate of increase before the shortage of forage began to cut down the excess population on overstocked areas by winter starvation was about the compound interest rate of 7.4 percent for all big game, 8.0 percent for deer, 7.5 percent for elk between 1921 and 1942, and for antelope as high as 17.0 percent between 1921 and 1931.

The hunter take for deer has never been heavy or over 7.8 percent up to 1937, or over 9.8 percent up to 1946, or over 12 percent up to 1950. Hunter take was as high for elk in 1935 as for deer in 1949. During the 24-year period, the hunter take of elk average 10.4 percent and for deer only 7.8 percent notwithstanding the fact that deer have more than twice the potential rate of increase. The hunter take of deer averaged 7.8 percent and the increase rate 6.4 percent or a total of 14.2 percent with a maximum potential of 54.9 percent or about 40 percent not accounted for.

TABLE 4. A comparison of the average numbers recorded for 1921 to 1925 and 1946 to 1950.

Animal	Average number 1921 - 1925	1946 - 1950	Annual rate of increase 1923 - 1948 Percent
Bighorn	14,480	9,960	—1.5
U.S. only	12,480	9,420	—1.1
Mt. Goat	18,320	20,420	0.4
U.S. only	8,740	14,050	1.9
Grizzly and Alaska brown bear	3,320	6,680	2.8
Moose	5,060	10,260	3.0
Black bear	44,000	95,200	3.1
Big game	670,800	2,753,200	5.8
Elk	50,440	214,000	6.0
Deer	524,800	2,369,800	6.2
Antelope	4,200	27,020	7.7

The hunter take of elk for the same period averaged 10.4 percent and the rate of increase 5.8 percent or a total of 16.2 percent with a maximum potential of 26.8 or about 10 percent not accounted for. That this nearly three-fourths of the maximum potential of the annual deer crop and somewhat less than one half of the maximum elk crop can ever be harvested is not possible, but game managers can hope to approach this optimum if they can avoid starvation, predator loss and disease.

If one considers big game as a whole, deer, elk and antelope are probably at the stage of recovery when the chief need is rational game management. They are more likely to suffer from overpopulation than from over harvest by hunters. The proper distribution of hunter take will reduce the take on underpopulated areas, increase the take on overpopulated areas and thus secure a more even distribution and protect not only the breeding herd but also the range and the land. A herd too heavily hunted can recover in a year or two but an overbrowsed range will require years to recover and may be almost permanently damaged.

Moose present a problem, for to date they have been regarded chiefly as a trophy animal. With this approach they are not likely to become important either for the production of meat or hunting recreation. Moose reproduce rapidly, however, and a year-old calf is a large animal if not a trophy. A biological and economic approach may yet make it an important element in the recreational program.

Grizzly and Alaska brown bear are important in Alaska but grizzly in the United States are limited to the more remote forests, mostly in the Northern Rockies and are not likely to increase to the point of becoming important game animals. The range of the mountain goat can apparently be greatly extended. The fact that three escaped in the Black Hills of South Dakota and soon increased to 300, far below their natural range on entirely different forage, would indicate that they might be extended almost as far as the ponderosa pine forests. Bighorn reproduce fairly rapidly, use a far wider range of forage than mule deer and give promise of again becoming important game animals. They are reported from 48 National Forests. Many recent plants have

been made and this may insure a continuation of the slight recovery indicated since 1940.

The rate of increase by no means uniform throughout the thirty years is for the whole period about as follows: Bighorn −1.5 percent or in the states only −1.1 percent, mountain goat 0.1 percent or in the states only 1.9 percent, grizzly and Alaska brown bear 2.8 percent, moose 3.2 percent, black bear 3.2 percent, total big game 5.8 percent, elk 5.9 percent, deer 6.1 percent, and antelope 8.4 percent.

At these rates Bighorn would drop to one-half the present number in 47 years or, if the states only are considered, in 54 years. Mountain goat just holding its own would, if the states only are considered, require 37 years to double the number. Grizzly and Alaska brown bear would require 25 years, moose 22, black bear 16, big game 12, elk 12, deer 11 and antelope 9 years to double in number. At the highest rate of increase following 1921, antelope doubled in 5 years, deer in 9, elk in 10 and big game in 10 years.

Soil Physics

Third edition. By L. D. Baver. John Wiley & Sons, Inc. New York 16, N. Y. 489 pp. $7.75. 1956.

Review by Stephen H. Spurr
University of Michigan

The expanding interest of forest scientists in soils matters, and the importance of the physical properties of soils in forest soils problems, make Baver's work on soil physics one of the basic texts required by the forest soils specialist.

First published in 1940, the second edition appeared in 1948. The present and third edition includes two new chapters dealing with soil irrigation and soil drainage.

Throughout the work, considerable new material has been added, including discussions of soil puddlability, the effect of chemical soil conditioners on soil structure, the diffusion process in soil aeration, soil moisture stress and plant growth, compaction in soil tillage, and wind-erosion. In some cases, the discussion is completely new, and in others on expansion of the material in the previous edition.

A notable change in approach has been in minimizing the use of *pF* in discussions of soil water, a concept earlier championed by Baver but one that failed to achieve widespread usage. Some of the older work on mechanical analyses of soils has also been eliminated.

The forest soils scientist will find the discussions of soil moisture measurement and other similar items perhaps not as fully developed as he would like. The author has kept them in perspective to the whole field of soil physics, however, and this fact alone should aid the forester in grasping the relation of his own interests to the larger problems of soils. Baver's book remains an excellent guide to the field it covers.

Effect of Slash Burning on Some Physical Soil Properties

BY
ROBERT F. TARRANT

THOUSANDS OF ACRES of logging slash are burned annually in the Douglas-fir region as a fire-protection measure. Whether or not such burning changes physical soil properties has not been thoroughly explored.

A series of studies has been conducted by the Pacific Northwest Forest and Range Experiment Station to determine the effect of slash burning on soil properties. The present study was made during 1954 to learn whether slash burning actually changes physical soil properties and how any changes might be influenced by the severity of burning. Several related phases have been reported previously (Tarrant, 1953, 1954a, and 1954b; Tarrant and Wright, 1955).

Methods

Two different soils were studied. One, from the upper Wind River Valley of southern Washington, was a pumicy sandy loam with a weakly developed mor humus layer. The other, from the H. J. Andrews Experimental Forest in the Cascade Range of Oregon, was a sandy clay loam with a mull humus layer. At both locations, plots were established in 1954 on areas that had been clearcut and subsequently burned in October 1953.

On each clearcut area, 33 undisturbed soil cores were collected from each of the following surface conditions:

Unburned	No evidence of disturbance during logging and no visible effect of fire.
Light burn	Where fire charred the surface of the forest floor but did not remove all litter from the soil.
Severe burn	Where fire removed all organic litter from the surface and in addition left the mineral soil highly colored.

Undisturbed soil cores were collected in steel cylinders of 350 cc. capacity and 3-inch depth. In the laboratory, percolation[1] tests were made on all cores after saturation. The cores were then subjected to a tension of 60 centimeters to determine macroscopic and microscopic pore space. Bulk density was calculated after oven drying. Cores were analyzed in random

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[1] *Percolation* refers to the passage of water through the soil profile, whereas *infiltration* refers to the entry of water into the surface half inch of soil. Since the effect of severe burning usually extends below the half-inch depth, the term *percolation* is considered to be applicable.

TABLE 1. Differences between treatment means compared with differences required for significance at the 95-percent level of fiducial probability.

Soil property and unit of measure	Differences between treatment means[1]		
	Unburned and light burn	Unburned and severe burn	Light burn and severe burn
		Pumicy Sandy Loam	
Percolation rate (cu. in./hr.)	22.15 (10.63)	16.87 (10.63)	39.02 (11.20)
Macroscopic pore space (percent by volume)	5.46 (3.07)	15.93 (3.24)	10.47 (3.07)
Microscopic pore space (percent by volume)	11.33 (3.78)	11.06 (3.59)	0.27 (3.59)
Total pore volume (percent by volume)	5.88 (2.95)	4.86 (2.95)	10.74 (3.11)
Bulk density (gm./cc.)	0.10 (.06)	0.07 (.06)	0.17 (.06)
		Sandy Clay Loam	
Percolation rate (cu. in./hr.)	2.49 (18.70)	43.96 (18.70)	46.45 (19.70)
Macroscopic pore space (percent by volume)	14.15 (2.46)	18.22 (2.59)	4.07 (2.46)
Microscopic pore space (percent by volume)	18.89 (2.37)	18.78 (2.25)	0.11 (2.25)
Total pore space (percent by volume)	4.74 (3.18)	0.56 (3.01)	4.18 (3.01)
Bulk density (gm./cc.)	0.06 (.05)	0.05 (.05)	0.12 (.06)

[1]Figures in parentheses are differences required for significance at the 95-percent level of fiducial probability.

order to avoid the possibility of concentrating any technique error within any one treatment. All analyses followed procedures suggested by the Forest Soils Committee of the Douglas-fir Region (1953).

Effects of Severe Burning

Baver (1940) stated: "Permeability of the soil for water is unquestionably a function of the amount of the larger pores." In this study, severe burning was clearly found to reduce[2] macroscopic pore space and percolation rate below levels for the same properties in unburned condition (Figs. 1 and 2). Microscopic pore space and bulk density, in contrast, were both increased by severe burning (Figs. 1 and 3). Direction of the change was the same in both soils; and the magnitude of change, when expressed as a percent of unburned soil (Table 2), was remarkably consistent. Macroscopic pore space was reduced to about 25 percent of its volume in unburned soil, and percolation rate to about 30 percent.

Total pore space was reduced as a result of severe burning in the pumicy sandy loam, but unchanged in the sandy clay loam.

The practical effect of a reduction in percolation rate is an increase in surface

[2]All references to reductions or increases in soil property measurements imply significance at the 95-percent level of fiducial probability. See Table 1 for statistical comparisons.

TABLE 2. Change in physical soil properties after light and severe burning (expressed as percent of same value for unburned soil).

Physical soil property	Light burn		Severe burn	
	Pumicy sandy loam	Sandy clay loam	Pumicy sandy loam	Sandy clay loam
Percolation rate	+93	+ 4	−71	−72
Macroscopic pore space	−26	+58	−77	−74
Microscopic pore space	+32	+55	+31	+54
Total pore space	+10	+ 8	− 9	+ 1
Bulk density	−11	− 8	+ 8	+ 7

runoff of water during wet periods, causing soil erosion and a reduction in the amount of water taken into the soil . Only beneath the heaviest concentrations of large fuels, however, do slash fires generate enough heat to burn organic matter within the mineral soil. Thus, severe burning occurs only in small and discontinuous patches. A study of some 75 field plots in the Douglas-fir region showed that less than 5 percent of the total surface of a logged and slash-burned area was severely burned. A similar figure on the proportion of severely burned soil surface after slash burning was reported from California (Vlamis et al., 1955).

Although severe burning definitely damages physical soil properties, it affects only a very small portion of the total area logged and slash burned. Therefore, it is concluded that severe burning exerts a minor influence under current slash-burning practice. Increased utilization of low-grade logs and small size stems will tend further to reduce the volume of heavy fuels left after logging, thus minimizing the extent of severe burns and soil damage during slash disposal.

Effects of Light Burning

Although the effects of severe burning are clearly defined, an anomaly is apparent when the results of light burning are studied. In the pumicy sandy loam, percolation rate (Fig. 2) on lightly burned areas was greater than that of the unburned

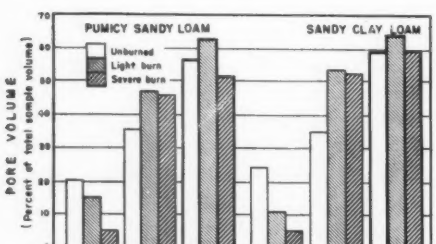

FIGURE 1. *Relation between soil porosity and surface condition after slash burning.*

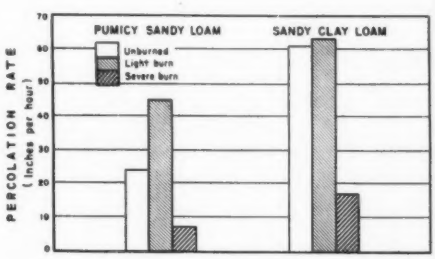

FIGURE 2. *Relation between percolation rate and surface condition after slash burning.*

condition, although macroscopic pore space (Fig. 1) was less. In the sandy clay loam, there was no difference between percolation rates in unburned and lightly burned soils, although again, macroscopic pore space was less. Microscopic pore space and total pore space were greater in both lightly burned soils than in their unburned counterparts. Bulk density of both lightly burned soils was less than that of the unburned soils (Fig. 3).

There is no ready explanation for the failure of percolation rate and macroscopic pore space to follow the usual relationship. Since the sequence of soil samples in laboratory tests was determined by random selection, there is no reason to suspect a concentration of analytical technique error in the lightly burned soils. Moreover, the changes in total pore space and bulk density in the two soils were highly consistent in both direction and amount (Table 2), although these soils were distinctly different in texture and were collected from cutting areas more than 100 miles apart. The inconsistencies in percolation rate and macroscopic pore space after light burning may be due in part to the highly aggregated character of the surface soils. Low values for bulk density (even after severe burning) are typical of Douglas-fir region soils, as evidenced by some 1,200 measurements now available for comparison.

Discussion

Some interesting associations are evident when changes in soil properties after both light and severe burning are expressed as a percent of the same value for unburned soil (Table 2). In both soils, the decrease in percolation rate after severe burning is very nearly balanced by the decrease in macroscopic pore space. For each soil, the increase in microscopic pore space following both light and severe burns is almost identical. Change in bulk density, except for severely burned sandy clay loam, is matched almost exactly by a change in total pore space in the opposite direction. Only

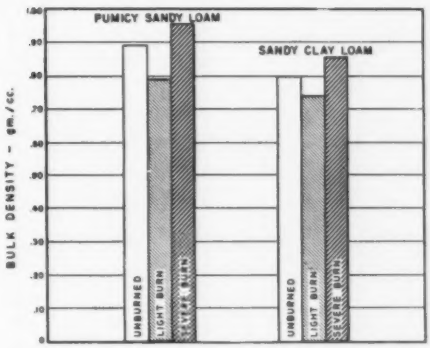

FIGURE 3. *Relation between soil bulk density and surface condition after slash burning.*

the relationship between percolation rate and macroscopic pore space in lightly burned soils fails to conform to established principles of soil water movement.

Conclusions

Severe burning seriously lowered the rate of moisture movement in the two soils studied. Light burning did not hamper the movement of water within the surface 3 inches of soil, although macroscopic pore space was reduced.

Severe burn occurred only in small, scattered patches that, combined, amounted to only a very small portion of the total surface of the slash-burned areas. For this reason, it is concluded that the over-all influence of slash burning on the moisture properties of the soils studied was of minor consequence. These findings are applicable only to intentional slash burning and should not be applied to areas in which repeated wild fires have occurred.

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Forestry Handbook

Edited for the Society of American Foresters by Reginald D. Forbes and Arthur B. Meyer. 1955. 1220 pp., 744 tables and illustrations. The Ronald Press Company, New York. $15.00.

Review by Herbert I. Winer and David M. Smith
Yale University

This impressive compilation, the work of no less than 145 contributors organized in 19 subject-matter committees, represents one of the most ambitious undertakings in the literature of American forestry. It would be difficult to estimate the enormous amount of unselfish labor that has gone into its preparation. The *Handbook* contains a wealth of information about all aspects of forestry, gathered from widely scattered sources, and presented in a form which will make it readily available to the practicing forester.

The *Handbook* does have some serious shortcomings. Before discussing them, we should stress our belief that its good features vastly outweigh the poor, which need not impair the usefulness of the book to the professional forester. Our belief that there are shortcomings may in fact be largely the product of an academic viewpoint. The ultimate test of the value of the *Handbook* actually lies in its usefulness to field foresters. It is reasonable to suppose that it will meet this test. The *Handbook* is almost certainly destined to become a vehicle on which a large body of forestry knowledge is carried into practice. Therefore, it is logical to scrutinize the first edition critically with a view to suggesting improvements for future revisions.

A "handbook of forestry" might take any of several different forms:

1. The *field manual*, intended exclusively for the use of professionally trained foresters and limited largely to material that can be presented in tabular form. This would consist primarily of detailed information that a forester needed and understood but that he would be foolish to attempt to memorize. In view of the fact that not all branches of forestry include a large body of knowledge that can be presented in this fashion, such a field manual would inevitably and properly dwell on some subjects at far greater length than others.

2. The *collection of condensed textbooks*, of primary usefulness to the layman interested in forestry. This approach would also be advantageous to the professional in those new or peripheral fields, such as range management, wildlife management, or photogrammetry, in which he might be called upon to operate but, for one reason or another, lacked formal training.

3. The *review of recent developments*, intended for the purpose of informing the main body of practitioners on advancements in knowledge and technique taking place in all parts of the continent This purpose is at pres-

ent served only partially by publications like the *Journal of Forestry*, which present most of the bits and pieces, but only rarely contain integrated reviews of developments in particular fields.

4. Finally there is the approach of the *encyclopedia*, in which an attempt would be made to summarize all existing knowledge about forests and forestry in North America. Although a work of this kind has recently been proposed (see *Journal of Forestry* 54: 50 (1956)), it does not seem that such a project could now be justified in view of its prospective cost as well as the inadequacy of existing knowledge.

As the preceding paragraphs suggest, the *Handbook* as a whole is something more than a manual but less than a text or encyclopedia. This inconsistency of approach appears within several sections, as well as from comparisons between sections. Not more than half a dozen sections are limited to the tabular approach of a true field manual. At the other extreme are a few sections that are short texts. Most of the *Handbook* falls somewhere in between, combining a generally successful compilation of tabular materials with less satisfactory attempts at exposition. Our basic criticism of the *Forestry Handbook* is that at one place or another it partakes of all of these different forms with widely varying degrees of justification. The aggregate effect is one of unevenness and inconsistency, to say nothing of the extent to which this diffusion of objectives has contributed to the size and cost of the publication.

One aspect of this diversity is recognized in the *Handbook's* preface, which states its intention to present

> *the working methods and techniques, formulas, tables, converting factors, and related data most commonly used in the practice of on-the-ground forestry in the United States and Canada. In addition, it brings together the information which, in our best judgment, is most generally useful in such allied specializations as watershed management, forest recreation, forest wildlife management, and forest range management.*

Yet even within those fields that are basic or central to the practice of forestry, the treatment varies widely. Thus, the logging section approaches—and the surveying section reaches—the status of a condensed text, although few, if any, foresters are without formal training in these subjects. On the other hand, the material on protection against insects and diseases is intentionally limited to two long and useful tables on types of injury and their control, with no attempt to touch upon many aspects of forest pathology and entomology treated in courses and textbooks.

To the extent that the *Handbook* is more than a manual, it has departed from its original purpose, a purpose implicit in the original title of "Foresters' Field Manual." This was to have been a volume of pocket size, containing not more than 500 pages, and restricted to quantitative and other tabular material for use in the field. (In 1947 it seemed reasonable to set a tentative price of $5 for the volume.) The first detailed prospectus indicated how this compactness was to be achieved: the "Manual" would be compiled for the technically-trained forester, thus eliminating the need for elementary material; peripheral fields like wildlife management would be ignored or treated very briefly; and volume tables, yield tables, and "similar material of local application" would be omitted.[1]

The decision to attack the project by forming 19 subject-matter committees certainly represented a feasible method of accomplishing the task. However, the inclusion of so many people in the effort made it almost inevitable that data of purely regional application would be introduced. The decision to treat some of the peripheral fields of forestry automatically produced some sections that could be presented only in prose. As expected, the manuscripts germinated slowly, but their subsequent growth was spectacular. Many tables were gathered from those fields that lent themselves to quantitative presentation; the committees for other fields tried to put into words what could not be expressed in figures. As a result, in 1951 the editorial committee was confronted by more than 2,000 pages of manuscript. The most diligent compression, involving maximum use of graphic and tabular techniques, could not be expected to reduce the mass by more than half, and the committee reluctantly raised its sights to a volume of 700 printed pages.

[1]The development of the present *Handbook* may be traced in the various committee reports published in the *Journal of Forestry*, especially 45: 776 (1947); 46: 201-205 (1948); 48: 59-61 (1950); 49: 130-131 (1951); 50: 146 (1952); 51: 50-51 (1953); and 53: 44-45 (1955).

It later became clear that most of the subject-matter committees remained unable or unwilling to retreat to the limitations of the original approach. As a result, the *Handbook* has developed into a compromise between a field manual for professional foresters and a collection of condensed textbooks.

The shortcomings that have resulted from attempting to strike a compromise between the requirements of the professional forester and those of the neophyte are strikingly exemplified in the section on silvics and silviculture. This section contains some good material readily adaptable to tabular presentation, including a serviceable dendrological key, a summary of the ecological characteristics of individual species, and a table of numbers of seeds per pound for various species, as well as examples of classifications of tree-vigor and site-types. However, some tabular information that might well have been included is missing. Among these omissions are: a table of number of trees per acre for different plantation spacings, dilution tables for silvicides, basic formulas for estimating costs of girdling and other stand improvement operations, classifications of species according to kind and degree of seed dormancy, an example indicating how stand density and volume would change during a sequence of well-regulated thinnings in an evenaged stand, and an example of the appropriate distribution of growing stock by diameter classes in a balanced, unevenaged selection forest.

Instead of providing such tabular information for the use of the trained professional, much of the space has been devoted to a discussion of silvicultural practice which is too condensed and incomplete to be reliable for the novice, yet too elementary to be of any assistance to the trained forester. For example, it seems peculiarly inappropriate to devote substantial space to the culture of Christmas trees when very little is mentioned about reproduction cuttings. The latter topic is not easily handled in condensed form and such a section might be unnecessary for the trained forester, but it certainly ought to be treated more thoroughly in any general discussion of silvicultural practice. The committee that prepared this section appears to have been less successful than most others in finding a satisfactory compromise between the conflicting objectives set for them. It should be noted, however, that our dissatisfaction with this particular section may merely reflect the fact that one's estimate of the quality of a given section of the *Handbook* varies inversely with one's knowledge of the subject.

The sections that have been allowed to develop into condensed textbooks often show a tendency toward oversimplified and occasionally dogmatic treatment of the subjects involved. Some subjects are inherently more susceptible to this risk than others, and the difficulty is naturally aggravated in a work that takes the whole of North America for its province. An instructive contrast is furnished by the recently published *Forestry Handbook for British Columbia*,[2] which combines the forms of field manual and textbook in more satisfactory fashion, largely because of its less ambitious, regional objective.

Since the *Forestry Handbook* is to remain in print, the pagination and other details have been set up so as to make revision easy. When the time comes for such revision, we believe that serious consideration should be given to returning to the original concept of the "Foresters' Field Manual." Those parts of the present manual that have been reduced to tabular form are likely to be the most useful. Therefore, it would seem best to concentrate on this approach in the future. The idea of including condensed "textbooks" on branches of forestry that are entirely new or distinctly peripheral serves an important purpose and ought to be retained. However, it is questionable whether the Society ought to involve itself in the preparation of a manual that purported to contain everything that anyone "really needed to know" about forestry. If there ever was a time when American forestry was really this simple, that time has passed.

If it does not prove to be feasible or desirable to return to the approach of a field manual, then the objective of presenting a series of condensed textbooks will probably be retained. In that event, an effort should be made to improve the quality of many of the sections. Much improvement could be achieved simply by making the objective clear to the

[2]Forest Club, University of British Columbia. 1953. Forestry handbook for British Columbia. Vancouver, B. C. xvii + 363 pp.

committees doing the work. It would also be necessary to subject manuscripts for the various sections to very critical review. A strenuous effort will be required to minimize such defects as regional bias, excessive generalization, and dogmatic judgments, which now mar several sections.

Regardless of how the form of the *Forestry Handbook* may evolve, there are several kinds of tabular information that might well be added. It is not clear why *Forestry Terminology* was not included or why *Forest Cover Types of North America* was presented in such drastically abbreviated form. The information on converting factors for units of measure ought to be expanded and put in more usable form, especially for units of wood measurement. There should also be a summary of statistical information on the forest resource, production, and trade. Other less important omissions could be mentioned. The reader will also note that some of the data, notably those on logging equipment, are already farther out of date than the unavoidable lag in publication would appear to justify.

There are, on the other hand, some places where space could be gained by deleting certain tabular information. On first consideration, it may seem just to devote 120 pages to volume and yield tables. However, if the tables in the *Handbook* are compared with such regional collections as that recently published for the Pacific Northwest,[3] it becomes apparent that a collection of all the good, useful North American tables would simply be too unwieldy for even a 2,000-page handbook of forestry. The practicing forester often needs to be in a position to select appropriate tables from a vastly greater number than that now in the *Handbook*. A few basic tables useful in constructing local tables might be included, perhaps supplemented by a complete and well annotated list of the tables available. It would probably be even better if the function of publishing collections of such tables were left at the regional level. This appears to be another instance in which the editors yielded to pressure and departed from original objectives which, in retrospect, appear to have been soundly conceived.

[3]Johnson, F. A., comp. 1955. Volume tables for Pacific Northwest trees. U. S. Dep. Agric., Agric. Handb. 92. 122 tables.

A final area for future improvement involves the various bibliographies, which are now of uneven quality and length. The editorial committee wisely decided against any attempt to furnish comprehensive bibliographies, but in many cases the process of selection has been too rigorous, leaving important gaps. Future editions of the *Handbook* should include more citations of monographs, specialized bibliographies, and other comprehensive treatments, especially for those subjects that are poorly adapted to tabular treatment. The present allocation of less than 2 percent of the total space to bibliographies hardly seems commensurate with their value to the reader who uses the *Handbook* as a guide to sources of fuller information.

The preceding comments are offered in full awareness that the best suggestions for improvement of future editions will come from practicing foresters in the field. It is to be earnestly hoped that these users will assume real responsibility for making such suggestions.

To a large extent, of course, the real value of the *Handbook* will be determined by the way it is used. As the editors intended, its chief usefulness will be neither to the specialist working in his own field nor to the forester who has access to a good working library. Except for new or peripheral subjects, the *Handbook* was originally planned to require a technical background in its readers; the compromises made in order to broaden its appeal actually increase the need for critical judgment in using the *Handbook*. The forester who believes that every aspect of forest management can be reduced to the level of the *Handbook* will find it an insidious companion.

Most of the foregoing criticism has been directed against what we believe to be an unfortunate expansion of the *Handbook* beyond its original scope. We should re-emphasize, however, that the *Handbook* is still eminently useful as a field manual. It will serve admirably as a convenient source of much material previously widely scattered through the literature. The comprehensive treatments of subjects in the fringes of forestry will also be invaluable. Our hope that the *Handbook* will become even more useful in the future does not in any way detract from the debt owed to the committees and editors who have compiled this first edition.

Maturity of Colorado Spruce Cones

BY
W. H. CRAM

LOW VIABILITY of spruce seed might be attributable to one or more factors such as immaturity, dormancy, cleaning, nursery practices, disease, insects and others. Investigations related to seed viability problems were initiated at the Forest Nursery Station in 1947. This work was undertaken primarily because of the importance of these problems in a breeding program. A previous report (Cram, 1951) revealed that seed dormancy was a major factor contributing to low germination of spruce seed. The present paper reports a preliminary study to determine the stage of maturity at which cones of Colorado spruce (*Picea pungens* Engelm.) should be harvested.

Many indices of maturity of conifer cones have been suggested and investigated. They include color of the cone, color and hardness of the seed, squirrel activity, summer temperatures and specific gravity of the cone. Cone color proved a fairly reliable index of ripeness for some pine species (Rudolf, 1940), but not for ponderosa pine (Maki, 1940) or for white spruce (Crossley, 1953). Firmness of the cone, color and brittleness of the seed have been reported as reliable indices of maturity for white spruce, but difficult and unreliable for pines. Embryo growth showed promise (Finnis, 1950) as a guide to seed maturity in Douglas fir, but was deemed too difficult to apply to white spruce in the field. Squirrel activity, which commenced some two weeks (Rudolf, 1940) to one month (Maki, 1940) prior to adequate maturity of the seed, is decidely unreliable as an index of cone ripeness. Summer temperatures from June to August were reported (Opsahl, 1952) as a safe basis for judging seed maturity of Norway spruce. Specific gravity of cones was found (Finnis, 1950) to give no indication of seed maturity in Douglas fir. On the other hand, reliable and occurate specific gravity tests of cone and seed ripeness have been reported for several pine species. (Fowells, 1949; Maki, 1940; Rudolph, 1940) Specific gravity of Colorado spruce cones appeared to be a reliable index of seed viability in unpublished work by the author.[1] Results suggested that cones should not be harvested until they float in water. Nevertheless no maturity test for cones of Colorado spruce has apparently been published in forestry literature.

Material and Methods

Two 40-year-old Colorado spruce trees,

The author is Plant Breeder, Forest Nursery Station, Canada Dept. Agric., Indian Head, Saskatchewan. The author wishes to express appreciation to Mr. John Walker, superintendent of the Forest Nursery Station, and to the Experimental Farms Service for support and facilities which made the study possible. Acknowledgement is made to P. O. Rudolf, Lake States Forest Experiment Station, and to the Horticulture Division, for constructive criticisms of the manuscript. Thanks are rendered to Mr. H. A. Worden, plotman, for his diligent assistance in the study.

each bearing large crops of cones in 1954, were selected for this investigation. They were isolated specimens growing in the lawn at the Forest Nursery Station. One tree, 42-3, manifested blue needle coloration, while the other, CIE, had green needles.

A minimum of 150 cones were harvested at five weekly intervals from September 1 to September 29 from branches of similar exposures on the two trees. Natural seed dispersal began on September 30 for one tree (42-3), and on October 3 for the other tree (CIE). All cones with visual signs of insect or other damage were discarded. For each tree on each date a random sample of 80 cones from the remainder were utilized for this study.

Moisture content of the cones at harvest was calculated from the loss of weight for three samples of two cones each, after drying in an oven for 24 hours at 100°C. Specific gravity was determined from the loss in weight in distilled water for six "bulked" samples of four cones each. The specific gravity of 50 individual cones was calculated from their respective weights to the nearest centigram and volume to the nearest centimeter. These 50 cones were segregated into their respective specific gravity classes. They were then allowed to dry under solar heat in the greenhouse until the seed was extracted on November 30. Seed was extracted from the cones in each specific gravity class separately by shaking the cones in a screen box. Seed so extracted, was the only seed utilized in this study as it corresponds to seed normally obtained by commercial extraction methods. A seed blower[2] was used to clean the seed after removal of the wings. It efficiently removed all empty and abortive seeds from the bulk samples. The seed was then weighed and counted, and the weight per 1000 and seeds per cone calculated.

Two greenhouse germination tests were conducted in order to estimate the viability of the seed of the two trees for the various dates of harvest. The first test involved stratified and non-stratified seed which was extracted from cones in the five most productive specific gravity classes. Regretably the results of this test were completely distorted by an excessive residue of methyl bromide, which was used to sterilize the germination medium. Hence a second and limited germination test with only non-stratified seed was begun on May 5. Unfortunately there was sufficient seed available from cones of only the two median specific gravity classes for four harvest dates and three replications of 25 seed each. Thus viability of seeds from cones of each respective date of harvest was based on the average germination capacity of 150 seeds.

Results

Table 1 presents a summary of the data for cone and seed characteristics of two Colorado spruce trees harvested at five weekly intervals. The data indicate that specific gravity and moisture content of the cones gradually decreased over the four-week period preceding natural shedding of seed. There was also an increase in the amount of sound seed extracted, while dormancy of the seed would appear to decrease or increase depending on the seed tree.

Average specific gravity values for 50 single cones and for six samples of four bulked cones in Table 1 were closely associated as indicated by a correlation value of 0.99. This would suggest that specific gravity was fairly accurately determined by the relatively crude method employed for individual cones. Specific gravity decreased on the average over a period of 28 days from 1.07 to 0.69. Thus the average specific gravity of cones from Colorado spruce approaches 0.70 just one to three days prior to natural seed dispersal.

[1]Cram, W. H. 1949. 1948 Annual report of the Forest Nursery Station, Indian Head, Sask. Canada Dept. Agric. unpub. Ottawa.

[2]South Dakota Seed blower, Model B.

TABLE 1. Cone and seed characteristics for two Colorado spruce seed-trees as determined by five weekly harvests in 1954.

Tree	Date of harvest	Specific grav.[1] of cones single	Specific grav.[1] of cones bulk	Cone moist.[2] percent	Seeds per cone	Germ.[3] cap. percent	Sdlgs.[4] per cone
CIE	Sept. 2[5]	1.04	1.02	57.2	42.2	?	?
	" 8	1.01	1.07	57.2	44.9	88.9	39.9
	" 15	0.99	1.03	57.0	78.8	86.3	68.0
	" 22	0.92	0.95	52.2	87.5	80.0	70.0
	" 29	0.76	0.71	35.6	113.3	73.8	83.6
423	Sept. 2[5]	0.98	1.01	58.3	36.1	?	?
	" 8	1.01	1.07	57.7	52.2	53.1	27.7
	" 15	0.95	0.99	58.2	32.6	48.7	15.9
	" 22	0.85	0.91	52.7	54.5	59.4	32.4
	" 29	0.71	0.67	35.6	67.1	65.0	43.6

[1]Av. specific gravity of 50 single cones and of 6 samples of 4 cones.
[2]Av. moisture content (percent wet wt.) for 3 samples of 2 cones.
[3]Germination capacity as percent of non-stratified seed sown.
[4]Production of seedlings per cone, germ. cap. × seeds per cone.
[5]Specific gravity determined 2 days after date of harvest, all others determined same day as harvested.

Moisture content of the cones decreased with approaching maturity from an average of 57 percent to an average of 36 percent just prior to seed shed. Moisture content and specific gravity of cones were associated with a correlation value of 0.97. Thus it would appear that specific gravity of cones and moisture content of cones are reliable indices of cone maturity for Colorado spruce.

Several interesting characteristics of the seed are also apparent from the data listed in Table 1. The amount of sound seed, which was extracted, increased with approaching maturity from 39 to 90 seeds per cone. The greatest increase of sound seed per cone was apparent in the last week prior to natural seed shed, namely from 71 to 90 seeds per cone. Results of the limited germination test suggested that viability of the seed varied as to seed-tree source and maturity. Dormancy of seed from one tree, increased, while that of the other tree apparently decreased with approaching maturity of the cones. Thus, in the four weeks preceding natural seed dispersal, potential productivity increased with cone maturity from 34 to 62 seedling per cone harvested.

Several characteristics of the seed, other than those reported in Table 1, were investigated and found to have little or no relationship to cone maturity. The weight per 1000 seed showed little variation for the five dates of harvest. This may be due to the high efficiency of the seed cleaning equipment used. Moisture content of the extracted seed decreased only slightly from 8.2 percent to 6.1 percent in the last four weeks of cone maturity.

Table 2 presents the frequency distribution of the specific gravity values for 50 individual cones from two trees harvested at five weekly intervals. It was noted that specific gravity of Colorado spruce cones varied from 1.15 to 0.64 in the four weeks preceding natural seed shed. Further, it was apparent that the range in specific gravity of cones at any one date of harvest was at least 0.15. Thus the average specific gravity of 50 cones would not portray an accurate picture of cone maturity at any one time. However, all cones from both trees had a specific gravity of less than

TABLE 2. Frequency distribution for specific gravity of cones as harvested from two Colorado spruce seed-trees at five weekly intervals expressed as percent of the 50 cones in each harvest.

Specific gravity class	Date of harvest and seed-tree									
	Sept. 2[1]		Sept. 8		Sept. 15		Sept. 22		Sept.29	
	423	CIE	423	CIE	423	CIE	423	CIE	423	CIE
.64- .67	....	....	....	....	....	....	....	....	20	....
.68- .71	....	....	....	....	....	....	2	....	42	18
.72- .75	....	....	....	....	....	....	2	....	24	42
.76- .79	....	....	....	....	2	....	12	....	12	22
.80- .83	....	....	....	....	2	....	16	....	2	12
.84- .87	....	....	....	....	4	....	32	12	....	6
.88- .91	....	....	....	....	8	....	22	26	....	....
.92- .95	20	....	4	6	34	14	14	46	....	....
.96- .99	54	20	34	28	34	44	....	16	....	....
1.00-1.03	20	42	46	42	12	38	....	....	....	....
1.04-1.07	4	36	10	16	2	4	....	....	....	....
1.08-1.11	....	....	6	6	2	....	....	....	....	....
1.12-1.15	2	2	....	2	....	....	....	....	....	....
Mean Specific Gravity	0.98	1.04	1.01	1.01	0.95	0.99	0.85	0.92	0.71	0.76

[1]Specific gravity of cones determined 2 days after harvest, but for same day as harvested for all others.

0.87 on September 29 just one to four days prior to natural seed shed.

The distribution in Table 2 showed that cones of tree 42-3 were generally riper than those of tree CIE at each date of harvest. This difference was substantiated by observations on natural seed dispersal, because tree 42-3 began shedding seed three days earlier than tree CIE.

Discussion

Validity of specific gravity and moisture content determinations as a means of testing cone maturity for Colorado spruce was substantiated. The physical basis of such a test was explained by the existence of a high correlation between specific gravity of the cones and moisture content of the cones. Time of harvest or maturity of the cones had a direct bearing on yield and viability of the seed (see Table1).

Individual trees of Colorado spruce were found to differ with respect to maturity of the cones as has been reported for pines and white spruce. In the present study, differences between trees would appear to be due to inherent characteristics, as most other contributing factors were similar.

It has been reported that all cones from an individual tree of pine were quite uniform in degree of ripeness. The specific gravity of cones from individual trees of Colorado spruce was found (Table 2) to vary greatly at any one date. Specific gravity of cones from one Colorado spruce tree ranged from 0.64 to 0.82, for a mean of 0.71, just one day prior to natural seed shed. It is possible that some or all of this variation may be due to the influence of seed or cone insects in cones which appeared sound and fully developed. For this reason an average value fails to portray a general picture of the cone ripeness at any one time.

The fallacy of using other than freshly-picked cones for specific gravity determin-

ations, as pointed out by Rudolf for pine (1940), is apparent from Table 2. Specific gravity of two-day-old (September 2) cones was considerably less than that of fresh cones, harvested five days later from the same tree. These results emphasis the importance of applying specific gravity maturity tests on freshly-picked cones in the field.

No clear relationship was found to exist between specific gravity of the cones and viability of the seed, as has been reported in the case of pine. No doubt viability of seed in the present study was distorted due to dormancy, which has previously been reported (Cram, 1951) for seed of Colorado spruce. When germination was considered in terms of seedlings per cone, however, a negative association was apparent between cone maturity and seedling production.

As a result of this study a specific gravity test for cone maturity of Colorado spruce, similar to that evolved for pine species, is proposed. A suitable test liquid for commercial seed collectors is boiled linseed oil, which has a specific gravity of 0.94. The cone crop from a tree may be harvested when 9 out of 10 cones float in linseed oil. However, for the exacting research, the most suitable test liquid would be turpentine, which has a specific gravity of 0.87. If harvesting of cones is delayed until all cones float in turpentine, then the maximum maturity of the cones and maximum seed yield would be assured.

Summary

Samples of 80 cones were harvested from two comparable trees of Colorado spruce [*Picea pungens* Engelm.] at five weekly intervals in 1954. Specific gravity of the cones ranged from 0.64 to 1.15, and on the average decreased from 1.01 to 0.69 in the four weeks preceding natural seed dispersal. Moisture content (wet weight) of the cones varied from 31.6 percent to 58.5 percent, decreasing on the average from 57.7 percent to 35.6 percent in the same period. Cones from the two trees differed with respect to their specific gravity and moisture content at any given date. The two cone characteristics, however, were closely associated with a correlation value of 0.99. Sound seed extracted over the four week period increased from 39 to 90 seeds per cone on the average. The greatest seed yield was obtained from cones harvested one to three days prior to natural seed shed. With approaching maturity of the cones, viability (i.e. dormancy) of the seed appeared to decrease or increase depending on the seedtree source. A negative association was apparent between maturity of the cones and productivity of seedlings per cone harvested.

Results suggest that commercial seed collectors should delay harvesting of Colorado spruce until 90 percent of the cones float in linseed oil. To ensure maximum seed yield, however, it would appear that harvesting should be delayed until all cones float in turpentine.

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Effect of Defoliation on Growth of Longleaf Pine Seedlings

BY
DAVID BRUCE

LONGLEAF PINE seedlings (*Pinus palustris* Mill.) in the grass stage suffer frequent defoliation—by fire, brown spot needle disease (*Scirrhia acicola* (Dearn.) Siggers), and other agencies. The grass stage of longleaf lasts until the seedlings have reached a root-collar diameter of about 1 inch, a process that may take from 2 to 30 years, depending on the rigors suffered by the seedlings. Defoliation generally retards growth, except when a fire rids a stand of brown spot by consuming or scorching the needles.

The effects of the different types of defoliation, however, are very difficult to isolate in the field. Once a seedling is infected with brown spot, the needle-killing becomes progressively more severe, but the rate is neither uniform nor predictable. Fire kills practically all the needles, but in addition to checking the brown spot infection it may set back competing vegetation. To avoid these complications, a study was made on artificially defoliated seedlings growing in a nursery on the Harrison Experimental Forest, in south Mississippi. The aim was primarily to secure basic data on growth loss, but an attempt was made to have the defoliations correspond, in time and degree, with those from natural causes.

Experimental Material

The seedlings were from local seed sown in April 1951. The nursery bed, which measured 4 by 52 feet, had received a presowing treatment of 4,000 pounds per acre of superphosphate and 600 pounds of 50-percent muriate of potash. During the first growing season there were 2 applications of 35 pounds per acre of elemental nitrogen (as 33 percent ammonium nitrate). In 1951 the bed was watered regularly with the nursery sprinkler system. In 1952 and 1953 the only supplement to rain was water that occasionally blew in when nearby nursery beds were watered. As protection against brown spot, seedlings were sprayed with 4-6-50 Bordeaux mixture about 5 times per year from 1951 through 1953.

In April 1952, when it was decided to use the seedlings in a test of defoliation, competition was diminished by thinning the stand from about 6 or 7 seedlings per square foot to an average of 2.7. In July 1952, when the seedlings were 1½ years old, they were further thinned to about 1.6 per square foot. This thinning removed all seedlings smaller than 0.39 inch or larger than 0.87 inch in diameter at groundline, and all that were exceptionally short or tall for their diameter class. The remaining seedlings averaged 0.57 inch in diameter and 1.9 inches in height to the base of the bud.

The author is Forester at the Southern Forest Experiment Station, Forest Service, U. S. Dept. of Agriculture.

FIGURE 1. *Clipping 30 percent of the foliage from a longleaf pine seedling. The three seedlings in the foreground have had, respectively, 60, 60, 90 percent of their foliage removed.*

Treatments

Seedlings were divided into two size classes:

Small—from 0.39 to 0.55 inch in diameter

Large—from 0.55 to 0.87 inch in diameter

There were 12 treatments—three degrees of defoliation in three different seasons and three double-defoliations. Each treatment was applied to 10 seedlings of each size class, and there were 50 check seedlings of each size. Treatment assignments to seedlings within each size class were completely random.

The defoliation was done by clipping the ends of the needles with shears (Fig. 1) so as to remove 30, 60, or 90 percent of the ocularly estimated average needle length. In July 1952 this was 14.4 inches. After treatment the average needle lengths were 8.6, 5.8, and 1.4 inches.

Clipping was done about the middle of the following months: July 1952, November 1952, and February 1953. These dates correspond generally with midsummer wildfires, the usual fall buildup of brown spot, and prescribed winter fires. To further imitate severe brown-spot defoliation, some seedlings were defoliated twice—to average needle lengths of 5.8 inches (60-percent defoliation) in July or November, and to 1.4 inches (90-percent defoliation) in November or February.

On July 3, 1952, February 17-18, 1953 and February 10-17, 1954, groundline diameters were measured to the nearest millimeter and heights to base of bud to the nearest 5 millimeters. In 1953, bud lengths were measured to the nearest 5 millimeters on February 17-18, March 16, and April 14-15.

Results

The degree to which the seedlings were defoliated had a greater effect on growth than the dates on which clipping was done. Seedling size affected growth but not response to defoliation. Both seedling size and degree of defoliation had significant effects on growth, at P=1 percent. Effects of season were significantly different at the 5-percent level.

The two-stage defoliation was generally the most severe treatment (Table 1 and Fig. 2). Seedlings defoliated in both July and November made only one quarter the height growth of check seedlings. However, the November-February combination permitted more growth than the 90-percent clipping in either July or November.

As was expected, the February 1953 defoliation had the least effect on seedling growth. Seedlings clipped in July 1952 grew better in 1953 than those clipped in November 1952. The July-treated seedlings grew only 0.4 inch in height in the last part of 1952, while all other seedlings

TABLE 1. Growth of defoliated longleaf pine seedlings, July 1952 to February 1954.[1]

Degree of defoliation (percent)	Single defoliation			Two-stage defoliation			Average
	February	November	July	November and February	July and February	July and November	
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
				HEIGHT GROWTH			
0	----	----	----	----	----	----	8.8
30	7.4	5.7	7.1	----	----	----	6.7
60	6.2	5.4	5.9	----	----	----	5.8
90	5.2	4.2	3.6	----	----	----	4.3
90 (two-stage)	----	----	----	4.4	3.4	2.1	3.3
Average	6.3	5.1	5.6	4.4	3.4	2.1	----
				DIAMETER GROWTH			
0	----	----	----	----	----	----	.65
30	.57	.52	.60	----	----	----	.56
60	.50	.51	.50	----	----	----	.50
90	.50	.33	.40	----	----	----	.40
90 (two-stage)	----	----	----	.39	.35	.22	.32
Average	.52	.45	.51	.39	.35	.22	----

[1]The following least significant differences (in inches) may be used to test the gaps between adjacent arrayed means:

Probability	Treatment means		Average of 3 treatments	
	Height	Diameter	Height	Diameter
0.05	2.6	0.09	1.5	0.05
.01	3.4	.12	2.0	.07

grew 0.7 inch. Thus they started the 1953 growing season somewhat smaller than seedlings in other treatments. This smaller average size accounts for most of their poorer growth in 1953, since size for size they grew almost as well as check seedlings after February 1953.

The growth loss caused by different degrees and seasons of defoliation was not distributed uniformly throughout the growing season (Figs. 3 and 4). Check seedlings made slightly more than half of their 1953 height growth after April 15. Seedlings 30-percent defoliated also made about half their growth after this date, but those more severely defoliated made only 40 percent of their growth late in the summer.

The seedlings clipped in July demonstrated their apparent early recovery by making half of their 1953 height growth after April 15, while November-treated seedlings made only 36 percent of their growth in the latter part of the growing season. Seedlings defoliated in February made more early growth but slightly less later growth than seedlings treated in July.

An interesting point is raised by the slight difference in growth indicated by height and diameter measurements. In terms of diameter growth the July 1952 treatments averaged about the same as the February 1953 treatments, while the height measurements indicate the July clipping to be the more damaging of the two. Measurements of longleaf seedling diameter in mid-February usually include some of the early spring growth, while height measurements to the base of the bud

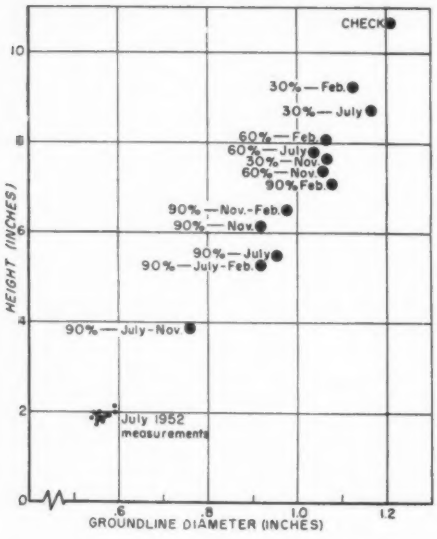

FIGURE 2. *Size in February 1954 of longleaf pine seedlings defoliated to different degrees and at various times after July 1952.*

do not. This suggests that there may have been more carry-over into the 1954 growing season of the February 1953 clipping effect than of the July 1952 treatment. The possibility was not checked, because the test was dismantled in February 1954.

Height growth showed the effect of seedling size more strikingly than did diameter growth. From July 1952 to February 1954, small check seedlings grew 0.60 inch in diameter and 5.4 inches in height, while large check seedlings grew 0.70 inch in diameter and 12.2 inches in height.

The defoliation appeared to cause no mortality. Five of the 240 defoliated seedlings were lost, and 3 of the 100 check seedlings. Of these, only 3 clipped seedlings died or lost their buds, and 1 check seedling had a bud that died. Other losses were due to fusiform rust or to damage during examination.

Discussion

Conditions in a nursery bed are quite different from those in the field. The study seedlings were larger than most natural or transplanted longleaf of the same age. Before the study ended, there was consider-

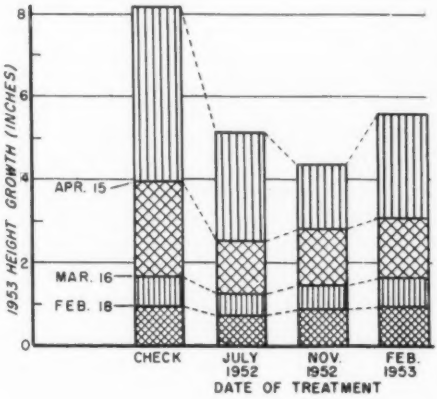

FIGURE 3. *Season of defoliation as related to amount and periodicity of longleaf pine height growth in 1953.*

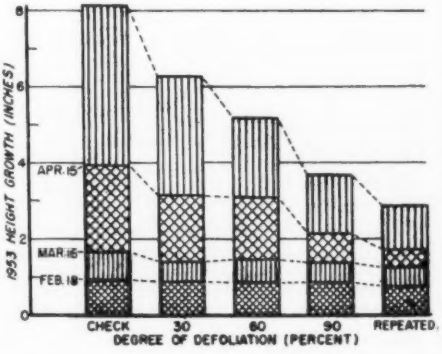

FIGURE 4. *Relation of various degrees of defoliation to amount and periodicity of longleaf pine height growth, 1953.*

able competition between seedlings, with the small possibly suffering more than the large. At similar densities, 70,000 to the acre, height growth of longleaf seedlings is greatly retarded in the field[1] Nevertheless, these seedlings grew better than uncrowded disease-free seedlings in the field. It is not known how this better growth might affect response to defoliation.

In November 1952 most seedlings defoliated in July had put on fresh needle growth (both new needles and extension of old needles). The clipped needles of heavily defoliated seedlings had grown 1 or 2 inches in length, on the average doubling their length of 1.4 inches in July. This new growth, including the distinct yellow-green basal extension of clipped needles, is possibly related to the good performance of the seedlings treated in July in comparison with those clipped in November. November defoliation interrupts the storage of food that normally takes place in this and the following months.[2] The large growth loss from November clipping appears to endorse the customary practice of waiting until January or February before prescribe-burning to control brownspot.

The problem is complicated, however, by the fact that brown spot builds up during the winter. Severely infected seedlings are very susceptible to fire, partly because they may be sapped of vigor but mainly because death changes needles from green insulation to dry fuel. Thus, each brown-spotted longleaf stand poses a fresh dilemma to the forester. Should he burn early and accept an almost certain growth loss? Or should he wait and hope that the disease will not kill a much higher proportion of needles before the January fire?

Since season of defoliation affects growth, it appears that estimates of brownspot defoliation need to consider not only the proportion of the needles dead at the time of the examination, but also the length of time that these needles have been dead. The proportion of needles shed prematurely and the color, distortion, and brittleness of the dead portions of retained needles offer clues.

Summary

Longleaf pine seedlings in a nursery bed in south Mississippi were 30-, 60-, or 90-percent defoliated with shears on three different dates: July 1952, November 1952, or February 1953. Growth was measured from the time of the first clipping, when the seedlings were 1½ years old, to February 1954. Some seedlings were clipped twice, first to average needle length of 5.8 inches and later to 1.4 inches (equal to 60- and 90-percent defoliation).

All defoliation caused growth loss, approximately in proportion to the amount of foliage removed. Two-stage defoliation was generally worse than a single 90-percent clipping. Clipping in November reduced growth significantly more than July treatment, while defoliation in February was least damaging. The degree to which the seedlings were clipped was more significant than the date on which clipping was done.

Defoliation generally affected periodicity as well as amount of growth. Check seedlings made slightly more of their 1953 growth after April 15 than before, while most of the defoliated seedlings made less of their growth after this date.

Large seedlings made much more height growth than small, but size had no significant effect on response to defoliation.

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[1]Wahlenberg, W. G. Longleaf pine. 429 pp. Washington, D. C. 1946. (See pp. 108-113.)

[2]Wakeley, P. C. Planting the southern pines. U. S. Dept. Agric. Monog. 18, 233 pp. 1954. (See pp. 80-83, 109.)

Viable Seeds from the Duff and Soil of Sugar Pine Forests

BY
CLARENCE R. QUICK

SINCE 1937, methods developed by the author[1] have been used successfully to isolate, identify, and germinate seeds of *Ribes spp.* from samples of duff and soil collected in sugar pine forests. As here described, similar methods were used to show variation in kind and quantity of seeds of many species occurring in soil and duff samples taken from the Stanislaus Experimental Forest, near Pinecrest, Tuolumne County, California.

Timber species found on the sampled areas were sugar pine (*Pinus lambertiana* Douglas), pondersoa pine (*Pinus ponderosa* Lawson), Jeffrey pine (*Pinus jeffreyi* Grev. & Balf.), white fir (*Abies concolor* (Gord. & Glend.) Hoopes), red fir (*Abies magnifica* A. Murr.), and incense cedar (*Libocedrus decurrens* Torrey.)

Rapid intrusion of brush into cutover timber land in the Sierra Nevada has long been a vexatious problem in timber management, and has been especially troublesome where regeneration of sugar pine is concerned. Climate, and the varying shade tolerance of the several timber species as described by Baker (1944, 1949), are important factors in this complex problem of forest land management which has been analyzed by Dunning with respect to tree classifications (1928) and site quality classification (1942), by Fowells for site improvement (1944), for the system of unit area control by Hallin (1951, 1954), and from the standpoint of the status of pine forests in California by Hughes and Dunning (1949).

On the Stanislaus Experimental Forest the principal species of brush which had markedly increased on adjacent previously logged areas, and which were expected to increase after the prescribed logging, were snowbrush (*Ceanothus cordulatus* Kellogg), deerbrush (*Ceanothus integerrimus* H. & A.), sweetbirch (*Ceanothus parvifolius* Trel.), green manzanita (*Arctostaphylos patula* Greene), bush chinquapin (*Castanopsis sempervirens* Dudley), Sierra Nevada gooseberry (*Ribes roezlii* Regel), Sierra Nevada currant (*Ribes nevadense* Kellogg), ground waxberry (*Symphoricarpos mollis* Nuttall), ground rose (*Rosa spithamea* Watson), bitter cherry (*Prunus*

[1]Unpublished reports 1937-39 in files of Blister Rust Control, Methods Development Unit, Forest Service, Berkeley, California.

The author is Forest Ecologist, Forest Service, U. S. Dept. Agric. Blister rust control investigations at Berkeley, California, are conducted by the Forest Service, U. S. Dept. of Agriculture, in cooperation with the University of California, College of Agriculture, through the School of Forestry. Research conducted by the California Forest and Range Experiment Station on the management of sugar pine provides guidelines for correlated studies on the improvement of blister rust control methods.

emarginata (Dougl.) Walp.), and western thimbleberry (*Rubus parviflorus* Nuttall).

Collection of Samples

Sixty-four samples of duff and soil were collected on September 23-26, 1947, from the forest floor under virgin stands of mixed conifers in the NW 1/4, sec. 26, and NE 1/4, sec. 27, T4N, R18E, Mt. Diablo Meridian. The samples were distributed over the areas concerned in 8 series. Each series of samples consisted of a set of 8 samples usually spaced at one-chain intervals along a line in a cardinal direction.

Field methods for the collection of samples may be described briefly as follows. The forest floor at time of collection was quite dry. A flat square boxwood frame, 11.2 inches inside measurement (2 square links of area—1/50,000 acre), was placed on the ground at the spot from which a sample was desired. Duff was cut through to mineral soil with a heavy knife around the inside edge of the frame. Duff and soil was removed down to rather solid undisturbed mineral soil, and placed in a 4-mesh sieve resting on a square of canvas. Material which would not pass the 4-mesh sieve was inspected for seeds and then discarded. The material was then worked on a 20-mesh sieve to reduce it to manageable size. This process requires dry soil. All material remaining on the 20-mesh sieve was placed in a cotton bag for greenhouse processing. It is estimated that the 64 samples taken to the greenhouse weighed about 700 pounds.

Some dry seeds in forest duff and soil will pass a 20-mesh sieve. From previous work it was known that practically all ribes and ceanothus seeds would be retained on a 20-mesh screen. All conifer seeds and most brush seeds, except for a very few such as azalea seeds, would likewise be retained. Inasmuch as the seeds of brushy plants were of primary concern in this study, collection and recovery procedures were simplified by discarding all material that would pass a 20-mesh sieve.

Preparation of Seed Concentrates

Methods used in the greenhouse for reduction of the duff samples[2] were similar to those described by Stone and Holt (1950), and had proven satisfactory on preliminary samples from the Stanislaus area. These methods were as follows: Each air-dry field sample was rubbed vigorously on a 12-mesh sieve. Material retained on the 12-mesh screen was placed in a No. 10 can and soaked over night in tap water. Material passing the 12-mesh screen was rubbed on a 20-mesh sieve. Material passing the 20-mesh screen was discarded; that retained was placed in another can of water and soaked over night.

The soaked subsamples were separately worked on a 20-mesh sieve under a stream of water from a "rose" nozzle until little additional material would pass the sieve. Residues retained by the 20-mesh sieve were separately spread on newspaper and dried. The sample retained wet on 12-mesh was resieved dry on 12-mesh screen. Dry material of this subsample now passing 12-mesh screen was added to the other 12- to 20-mesh subsample of the same field collection. This composite 12- to 20-mesh subsample was resieved dry on the 20-mesh screen.

At this stage of sample reduction each field collection consisted of two air-dry subsamples, one retained on 12-mesh screen and the other on 20-mesh screen. Most of the dirt and partly decomposed duff had been removed from the samples by soaking, washing, rubbing and sieving.

Each subsample was now processed separately in a small "Clipper Grain, Seed, and

[2]Frank A. Patty, Blister Rust Control, Forest Service, Region 5, assisted the writer in reducing the field samples to seed concentrates, in inspecting the seed concentrates, and in recording the data on seeds found by visual inspection.

Bean Cleaner," with screens measuring 9.75 × 15 inches. This seed cleaning mill was run by an electric motor of 1750 RPM belted so that the drive shaft of the mill had a speed of about 430 RPM. The first run of each subsample through the mill was made with a minimum of air from the fan. The "heavy overs" and the "middlings" were passed through the machine twice. The "light overs" and the heavy overs were then discarded. The "downs" and the middlings were combined to make the seed concentrate. This concentrate was now milled with maximum air blast. The downs—largely rocks—were passed through the mill 3 times, and then discarded. The light overs, heavy overs, and middlings were combined to make the final seed concentrate from the mill.

The reduced sample was stirred into a saturated solution of calcium chloride. Materials which sank in this heavy solution—mostly rocks—were discarded. Material which floated was removed to a small 20-mesh screen, washed immediately in much running water, and placed on a paper towel to dry. The specific gravity of a saturated solution of calcium chloride in water is approximately 1.4. Most seeds and most other organic matter will float in this heavy solution, and most rocks will sink. Tests in previous work[1] had shown that dry seeds of ribes and other brush species could be exposed to this solution without harmful effects on seed viability for the short periods necessary for the separation procedure. When thoroughly dry, the seed concentrate was rubbed carefully by hand on a 20-mesh sieve, then placed in a porcelain evaporating dish and cautiously winnowed with the breath. Material remaining in the porcelain dish was inspected for seeds, and then cultured for germinable seeds.

All discarded material was inspected casually, and some material with considerable care. A few seeds were lost in the various discarded portions, but the great majority of seeds retained on a 20-mesh sieve ended up in the final seed concentrates. Most of the mineral matter in the final seed samples was porous volcanic rock which had about the same specific gravity as ceanothus and manzanita seeds.

Identification and Culture of Seeds

Ceanothus, manzanita, and other distinctive kinds of seeds were readily found and identified in the seed concentrates. Ribes seeds and some other seeds, because of their dark color, dull surface, and irregular angular shape, were very difficult to identify in the final seed concentrate. Thus visual inspection detected a higher proportion of some species of seeds than of others.

Seeds of many plants, especially woody plants, native to the timbered portions of the Sierra Nevada will not germinate immediately, even if seed coats are readily permeable to, or are made readily permeable to water. Many such seeds are satisfactorily conditioned for prompt complete germination at greenhouse temperatures by stratification in a moist, aerated condition for some weeks or months. General germination methods, and specific methods for many species of native woody plants of California are described by Mirov (1940), by Mirov and Kraebel (1937), and by the Forest Service (1948). Quick (1935) has described methods for forcing germination of several species of ceanothus seeds.

Seed concentrates after visual inspection were cultured individually in steam-sterilized river sand wet with a dilute mineral nutrient solution. Although the coats of most kinds of ceanothus seeds are impermeable to water, they are easily made permeable by a treatment in boiling water for 5-30 seconds. Therefore ceanothus seeds were picked out of the subsample concentrates and immersed in boiling water for 6 to 7 seconds, abruptly cooled in cold water, then cultured in sand. Few manzanita seeds are water-permeable, but no satisfactory pre-stratification treatment similar to the hot-water treatment for ceanothus seeds is known. Thus manzanita

TABLE 1. Seeds observed in sample concentrates, seedlings produced in cultures from 64 duff-and-soil collections, and percent of seedlings produced to seeds observed, Stanislaus Exptl. Fores', Pinecrest, Calif.

Kind of plant	Screen size of sample	Total observed seeds	Total seedlings produced	Mean seedlings per sample[1]	Percent seedlings to seeds
Ceanothus species	(4 -to-12-mesh)	249	188	3.1	75.5
do.	(12-to-20-mesh)	3027	1890[2]	37.3[3]	78.9
Ribes species	All	67	191	3.2	285.0
Manzanita	All	89	14	0.2	15.7
Other dicot species[4]	(4 -to-12-mesh)	126	20	.03	15.9
do.	(12-to-20-mesh)	590	551	9.2	93.4
Grasses[5]	All	....[6]	184	3.1	....[6]
Totals		4148	3038[2]	56.4[3]	86.4

[1]Each collection sample represents two square links of area (1/50,000 acre).

[2]Ceanothus seeds of some collections were subsampled; 635 known seeds were not cultured; percentages were adjusted.

[3]This figure includes an estimate of germination of ceanothus seeds which were not actually tested.

[4]Includes lily and iris seeds and seedlings.

[5]Includes sedge and rush seedlings.

[6]Grass seeds, if seen and identified, were included with assorted dicot seeds.

seeds were cultured for stratification and germination as found. Two field samples, one with 38 manzanita seeds and another with 29, accounted for most of the manzanita seeds recovered.

The final samples resulting from the concentrating procedures were cultured in sand as if to grow immediately, but prior to greenhouse germination test were stratified at 2.2° C. (36° F.) for about 14 weeks. After a 5 weeks' germination test in the greenhouse the cultures were re-stratified, this time at 0° C. (32° F.) for about 20 weeks, and re-germinated in the greenhouse. Seeds of some species of native plants require no stratfiication prior to germination, but for simplicity of procedure and for economy of time all cultures were stratified prior to greenhouse germination tests. This may not have been optimum treatment for some kinds of seeds. With the material at hand, however, it was believed that a greater number of dormant seeds would be killed by long periods in moist cultures at greenhouse temperatures, prior to a necessary stratification treatment, than readily germinable seeds would be killed by an unnecessary stratification treatment.

Discussion of Results

Table 1 summarizes number and kind of seeds found by visual inspection of seed concentrates from the 64 field collections, and compares observed seeds with seedlings produced in sand cultures. All collections were made under stand-condition classes (Hallin, 1951) commonly found on the Stanislaus Experimental Forest. In general this is a virgin, over-mature, mixed conifer forest containing large amounts of sugar pine in the overmature age class.

Seeds of deerbrush in general are considerably larger than seeds of snowbrush and sweetbirch. Almost all deerbrush seeds are retained on a 12-mesh sieve, while almost all snowbrush and sweetbirch seeds will pass a 12-mesh sieve. This difference

TABLE 2. Average number of seedlings produced in selected groups of samples representing five condition classes of timber overstory.

Samples	No. of samples	Timber overstory[1]				Average number of seedlings produced per sample			
		Major tree species[2]	General age[3]	Reserve[4]	Brush on area[5]	Ceanothus species	Ribes species	Other dicot species	Total[6]
CJ-CK	2	SP	Overmature	Plus	Plus	491.5	None	1.0	492.5
BC-BG	5	SP	Overmature	Minus	Minus	7.8	0.6	None	8.4
CR-CT	3	WF,SP	Mature	Plus	Minus	2.0	None	0.3	3.0
CZ-DC	4	SP,PP	Immature	Plus	Minus	33.0	10.5	5.8	49.3
CU-CY	5	SP	Immature	Plus	Minus	51.8	1.8	0.6	54.8

[1]Essentially no timber understory in sample groups listed.
[2]Tree species: PP—Ponderosa pine, SP—Sugar pine, and WF—White fir.
[3]General age of stand: Immature (75 to 150 years of age), Mature (150-300 years of age), and Overmature.
[4]Reserve. Growing stock suitable for carrying as reserve after logging considered adequate (plus), or inadequate (minus) for specific unit areas.
[5]Brush. Kind and amount of brush on specific unit areas expected to require (plus), or not to require (minus), eradication prior to forest regeneration.
[6]A few manzanita seedlings and grass (monocot) seedlings, not recorded in the columns, are included in the totals.

in size was used in the data as an approximate species separation of ceanothus seeds and resulting seedlings.

Because of the relation between numbers of seedlings produced and seeds observed, considerable numbers of ribes seeds, and seeds of assorted herbaceous dicot species in the 12- to 20-mesh subsample apparently were not observed in the seed concentrates. Apparently most ceanothus seeds were found by inspection—and most of them grew. The low yield of manzanita seedlings from the known seeds was consistent with previous experience. Grass (including sedge and rush) seeds and seedlings tended to be concentrated in a few collections. Ceanothus seeds outnumbered all other seeds combined, and were found in more than 75 percent of all collections. Some of the 8 series of samples contained very few ceanothus seeds, however, and a few samples contained no seeds at all. About 70 seeds of a mistletoe, believed to be *Arceuthobium campylopodum* Engelmann, were found in the seed concentrates by visual inspection, but no mistletoe seedlings developed in culture.

A total of 635 ceanothus seeds, picked out of the 12- to 20-mesh subsamples of 3 collections which contained a great many ceanothus seeds, were not cultured. The pertinent percentages of ceanothus seedlings to seeds found by visual inspection have been adjusted in the tables by proportion.

Table 2 summarizes average seedlings per sample resulting from selected samples classified by overstory stand-condition classes. Samples CJ-CK and BC-BG were collected under overmature sugar pine with essentially no coniferous understory. Samples CJ-CK represent a patch of dense ceanothus brush under an open stand of very large old sugar pines. Samples BC-BG were collected under a similar stand of sugar pine with essentially no brush on the forest floor. In Table 2 observe also that samples collected under immature overstory contained many more seeds of all sorts than samples collected under mature overstory, or under overmature stands without brush (samples BC-BG).

Great variability in average number and kind of viable seeds is apparent from all data shown in Tables 1-3. There was even greater variability within some series of samples. For example, a series of samples (CJ-CP) was collected at one-chain inter-

TABLE 3. Average number of seedlings produced in selected groups of samples representing five condition classes of timber understory.

Samples	No. of samples	Timber understory[1, 2] Major tree species[3]	Stocking[4]	Brush on area[5]	Average number of seedlings produced per sample Ceanothus species	Ribes species	Other dicot species	Total[6]
CB-CC	2	WF	Under	Plus	68.5	2.5	None	71.0
CD-CI	6	IC	Under	Plus	18.9	0.2	13.5	32.6
BV-CA	6	WF	Under	Minus	27.0	None	0.3	27.5
AU-AX	4	WF	Normal	Minus	15.7	10.0	0.5	26.2
BJ-BN	4	IC	Normal	Minus	0.8	None	6.7	7.8
BO-BS	5	WF	Normal	Minus	0.2	0.6	0.8	1.6

[1]Timber overstory in all cases was overmature sugar pine.
[2]General age of understory in all cases was large saplings (10 feet height, to 4 inches DBH).
[3]Tree species: IC—Incense cedar, and WF—White fir.
[4]Stocking. Specific unit areas were considered overstocked, normally stocked, or understocked.
[5]Brush. Kind and amount of brush on specific unit areas expected to require (plus), or not to require (minus), eradication prior to forest regeneration.
[6]A few manzanita seedlings and grass (monocot) seedlings, not recorded in the columns, are included in the totals.

vals along a north-south line. Numbers of ceanothus seedlings resulting from individual collections along this line follow: 618, 365, 156, 106, 19, 30, and 6; a total of 1300, and an average of 186. Numbers of assorted dicot seedlings resulting from a series of samples (DA-DG) collected at one-chain intervals along another north-south line, from timber to timber across a narrow neck of meadow in timber-type, follow: 0, 2, 21, 278, 52, 42, and 1; a total of 396, and an average of 57. Numbers of ceanothus seedlings for this same series of 7 samples follow: 65, 9, 2, 1, 0, 14, and 20; a total of 111, and an average of 16. Numbers of viable ribes seeds varied similarly to ceanothus seeds, and numbers of grass seeds similarly to assorted dicot seeds.

Table 3 summarizes results from selected series of samples classified by understory stand-condition classes. The timber overstory in all cases was overmature sugar pine. Notice that numbers of ceanothus seedlings from brushy areas (samples CB-CC and CD-CI) average appreciably higher than ceanothus seedlings from non-brushy areas, and that understocked understories average well above normally stocked understories.

The occurrence of ribes seeds in the many collections was more sporadic than the occurrence of ceanothus seeds. Many individual samples produced no ribes seedlings, but ribes seeds were widely distributed and surprisingly numerous. One sample produced 38 ribes seedlings, and one series of 8 samples averaged 10 ribes seedlings per sample. One complete series of 8 samples, and a total of 36 individual samples contained no ribes seeds at all.

The column in Table 1 reporting average seedlings per sample is a bit imposing, especially when the average figures are converted to a per-acre basis. Individual field samples represented only two square links of area, that is, only 1/50,000 acre. This extreme smallness of sample and the disproportionate distribution of samples among stand condition classes on the area should be held in mind. It can then be stated that the average viable seed content of duff and soil under virgin, largely overmature, timber on the sampled areas of the Stanislaus Experimental Forest, on a *per acre* basis, was found to be 155,000 seeds of deerbrush, an estimated 1,865,000 seeds of snowbrush and sweetbirch, 160,000 seeds of ribes, 10,000 seeds of manzanita, 475,000 seeds of assorted dicot plants (in-

cluding seeds of the iris and lily families), and 155,000 seeds of grasses (including seeds of rushes and sedges); an average total of about 2,820,000 viable seeds per acre.

Summary

The increase of brush following logging in the Sierra Nevada of California has long been a troublesome problem. Duff samples were collected from virgin mature forest to determine if kind and amount of post-logging brush could be approximated from the kind and number of viable seeds found in relatively few small duff samples. Sixty-four samples of duff down to mineral soil were collected in September 1947 under virgin mixed-conifer timber on the Stanislaus Experimental Forest, Dodge Ridge, Pinecrest, Tuolumne Co., Calif. Each small sample represented 1/50,000 acre of area. The duff and soil collections were reduced by a variety of methods to seed concentrates of small volume. These seed concentrates were inspected; then cultured in autoclaved sand wet with mineral nutrient solution. Seedlings resulting from germination cultures indicated that the average viable-seed content of duff and soil under virgin, largely over-mature timber on the sampled areas, on a *per acre* basis, was 1,865,000 seeds of snowbrush and sweetbirch (*Ceanothus cordulatus* Kell. and *C. parvifolius* Trel.); 475,000 seeds of assorted dicot plants(including seeds of the iris and lily families); 16,000 seeds of ribes (largely *Ribes roezli* Regel); 155,000 seeds of deerbrush (*Ceanothus integerrimus* H. & A.); 155,000 seeds of grasses (including seeds of rushes and sedges), and 10,000 seeds of manzanita (largely *Arctostaphylos patula* Greene); a total of about 2,820,000 viable seeds per acre.

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Effect of Soaking Position on Treatability of Pine Fence Posts

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FENCE POSTS may be arranged in a treating tank in either a horizontal or a vertical position for full-length preservative treatment by the cold-soak method. Each type of post arrangement has its advantages and disadvantages when compared to the other.

In many instances horizontal treatment is more practical, and perhaps more economical, than vertical treatment. Although horizontal tanks often have limited capacity, they generally are more readily available in farm communities than vertical tanks. The most important consideration, however, is whether either method of post arrangement provides better treatment as measured in terms of greater amounts of liquid absorbed and by deeper penetration of the wood by the preservative solution.

Buckman and Pera (1952) reported that an increase in the hydrostatic pressure of the treating solution in their cold-soak treatment of small wooden blocks and cylinders resulted in higher preservative absorptions and deeper toxicant penetrations. They found that the relationship between depth of immersion in an oil solution of pentachlorophenol and liquid absorption was linear, or practically so. Their investigation also showed that the highest absorptions occurred in the butts of posts cold-soaked in a vertical position, with progressively decreasing preservative absorptions and penetrations occurring from the butt to the top. Similar results were obtained by the senior author (1948) in a limited study of the preservative treatment of white pine posts at low temperatures.

The authors know of no studies, however, of the relative effects of horizontal and vertical positions *per se* on the treatment of full-size fence posts. Thus, the Illinois Agricultural Experiment Station initiated this study to determine what effect soaking position might have on the results of cold-soaking shortleaf pine (*Pinus echinata* Mill.) posts in an oil solution of pentachlorophenol.

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Materials and Methods

Posts. Forty-seven shortleaf pine posts were selected for straightness, freedom from defects, and uniformity of size, from several hundred peeled and air-seasoned posts cut from plantation thinnings. The average length of the posts was 6.8 feet, and the average midpoint diameter was 3.7 inches (Table 1). Forty-four posts were treated, and three were used in moisture-content determinations.

The average moisture content of three randomly selected posts was about 15 percent, based on a sample cut from the midpoint of each post and oven-dried to constant weight at 105°C.

Treating solution. The posts were cold-soaked 24 hours in a solution of 5 percent pentachlorophenol in No. 3 fuel oil. Although not tested, the oil probably had the following specifications:

Specific gravity	0.856
Viscosity at 100°F., SSU	36
Initial boiling point	374°F.
End boiling point	565°F.

Treating methods. The posts were randomly assigned to treatments. Nineteen posts were treated vertically in a round tank 8 feet deep, butts downward, with approximately 7 inches of liquid covering the tops. In a separate horizontal tank 5 groups of 5 posts each were treated in a horizontal position, with each group or layer separated from the next by laths one-half inch thick. Measurements indicated that the head of liquid at the midpoint of each horizontal layer was approximately as follows:

First layer (top)	4 inches
Second layer	8 "
Third layer	12 "
Fourth layer	16 "
Fifth layer (bottom)	20 "

Thus the design of the experiment allowed us to measure differences in solution absorption and penetration between two groups of posts and among layers of posts treated in a horizontal position.

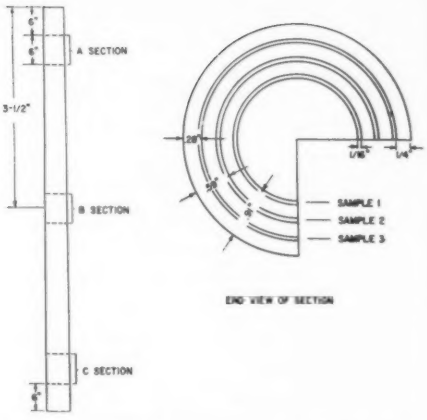

FIGURE 1. *Toxicant sampling system showing the location of sections in post and the location of samples in each section of post.*

Each post was weighed before and after treatment to the nearest 1/100 pound, and the absorption of solution in pounds per cubic foot of post was computed to the nearest 1/100.

The depth of sapwood penetrated by the solution and the thickness of sapwood were measured to the nearest 1/100 inch on split increment cores obtained from the midpoints of 44 posts.[1] The "dye-bed" technique (Walters 1948) was used to analyze solution penetration.

Figure 1 shows the method of sampling the posts for toxicant concentration. A cylinder about 6 inches long was cut from the top (Section A), midpoint (Section B), and butt (Section C) portions of each post. Each cylindrical section was centered in a lathe and turned against a cutting tool. Thus a 1/16-inch layer was collected for chemical analysis from each of the following radial depths of each section: 0.28-, 0.59-, and 0.91-inch.

[1]Measurements on one post were subsequently abandoned as questionable.

TABLE 1. Size of shortleaf pine posts cold-soaked 24 hours in horizontal and vertical positions.

Position of posts in tank	Number of posts treated	Mid-diameter, in.			Length, ft.			Volume, cu. ft.			s^1
		Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	
Horizontal	25	4.7	3.0	3.7	7.1	6.5	6.9	0.86	0.33	0.52	0.12
1st layer (top)	5	4.7	3.3	4.0	7.1	6.7	6.9	0.86	0.42	0.61	0.16
2nd layer	5	4.4	3.4	3.7	7.0	6.8	6.9	0.72	0.44	0.53	0.11
3rd layer	5	4.4	3.4	3.7	7.0	6.7	6.9	0.71	0.44	0.53	0.11
4th layer	5	4.0	3.3	3.6	7.0	6.5	6.8	0.61	0.39	0.50	0.10
5th layer (bottom)	5	3.6	3.0	3.3	6.9	6.7	6.8	0.48	0.33	0.41	0.07
Vertical	19	5.0	3.0	3.8	7.1	6.6	6.8	0.96	0.32	0.55	0.18
All posts	44	5.0	3.0	3.7	7.1	6.5	6.8	0.96	0.32	0.53	0.15

[1]Standard deviation.

Approximately 10 months were required to collect and analyze the 390 samples for pentachlorophenol content. The three sections representing a post were grouped, and the groups were selected at random for analysis in order to eliminate any variation which might develop as a result of "creep" of the preservative solution. With the following exceptions, the standard method for the determination of pentachlorophenol in wood adopted by the American Wood Preservers' Association (AWPA, 1952) was used for determining the toxicant concentration:

1. Lathe turnings (shavings) were used in place of increment cores.
2. The organic matter was destroyed in an electric muffle furnace following an initial 10-minute burning period on a Meker burner.
3. The ignited sample was placed in a wide-mouth Erlenmeyer flask for the remainder of the analysis.
4. The neutralized ignition mixture was not filtered following the addition of 0.1N silver nitrate solution.
5. One ml. nitrobenzene was added to the mixture before the Volhard indicator solution.

Three measurements of toxicant were missing from data for posts treated in each position. This was taken into account by least squares analysis using "dummy variates."

Results and Discussion

Tables 1, 2A, 2B and 3 show the results of measuring and chemically analyzing the treated posts. Tables 4 and 5 show analyses of variance for data obtained from the measurement of toxicant concentration in posts.

The average volume for the horizontal posts was 0.52 cubic foot and the standard deviation (s) was 0.12 cubic foot (Table 1). The average volume for the vertical posts was 0.55 cubic foot with a standard deviation of 0.18 cubic foot. Thus, the vertical group had greater variation (but not significantly so) in the volumes of the individual posts than the horizontal group.

The average volume of the top layer of horizontal posts was somewhat larger, and that for the bottom layer was somewhat smaller than the average volumes of the other layers. The top layer also had more variation in post volumes than the other layers did.

Post treatments. The average absorption for all posts was 4.73 pounds per cubic foot (Table 2a). The average absorption for the vertical posts was 5.21 pounds. In contrast, the average absorption for the horizontal posts was only 4.37 pounds, or slightly less than 84 percent of the average for the vertical posts.

The standard deviation for solution absorption for the vertical posts (1.38

TABLE 2A. Absorption and penetration of shortleaf pine posts cold-soaked 24 hours in fuel-oil solution of pentachlorophenol.

Position of posts in tank	Absorption of solution, lb/cu. ft.				Sapwood penetration, inches				Sapwood penetration, percent			
	Max.	Min.	Av.	s[1]	Max.	Min.	Av.	s[1]	Max.	Min.	Av.	s[1]
Horizontal	7.07	2.58	4.37	1.03	2.20	0.35	1.21	0.50	100	18	65	24
1st layer (top)	5.17	2.58	3.89	0.97	1.72	0.35	0.96	0.53	78	18	45	22
2nd layer	4.75	3.76	4.06	0.40	2.00	0.62	1.20	0.62	91	37	62	22
3rd layer	4.07	3.04	3.67	0.39	1.32	0.72	1.02	0.25	66	39	53	12
4th layer	7.07	4.20	5.44	1.47	2.20	1.18	1.75	0.37	100	69	94	14
5th layer (bottom)	5.67	4.29	4.77	0.56	1.78	0.78	1.12	0.39	100	45	69	21
Vertical	8.28	1.48	5.21	1.38	2.25	1.18	1.46	0.26	100	48	88	15
All posts	8.28	1.48	4.73	1.25	2.28	0.35	1.31	0.43	100	18	75	24

[1]Standard deviation.

TABLE 2B. Toxicant concentration in posts cold-soaked 24 hours in fuel-oil solution of pentachlorophenol.

Position of posts in tank	Average pentachlorophenol concentration, percent							
	Section			Depth of radial sample, inches				
	Top (A)	Middle (B)	Butt (C)	0.28	0.59	0.91	Post	s[1]
Horizontal	.612	.597	.594	.700	.615	.484	.601	1.238
1st layer (top)	.623	.619	.578	.728	.622	.471	.607	1.205
2nd layer	.528	.516	.519	.603	.558	.403	.521	0.485
3rd layer	.520	.504	.509	.622	.500	.410	.511	0.444
4th layer	.704	.742	.779	.792	.777	.656	.742	1.845
5th layer (bottom)	.701	.603	.586	.757	.620	.478	.625	0.560
Vertical	.509	.745	.809	.766	.694	.605	.690	0.930
All posts	.567	.661	.687	.729	.650	.535	.639	1.130

[1]Standard deviation.

pounds) was higher than that for horizontal posts (1.03 pounds), but the difference was not significant. The variances include treating effects, so that variation due to post position has not been shown.

The vertical posts averaged 88 percent of the sapwood treated in comparison to 65 percent for horizontal posts. The standard deviation (24 percentage points) for horizontal posts was considerably greater than that for vertical posts (15 percentage points), suggesting that the sapwood on the vertical posts was more uniformly treated; however, since all of the sapwood on some posts was treated and since heartwood is more difficult to treat than sapwood, we are unable to say what the standard deviation might have been had the treatment been free from the inhibiting effects imposed by the heartwood.

The concentration of pentachlorophenol in the vertical posts averaged 0.690 percent[2] (Table 2B), whereas the horizontal posts averaged only 0.601 percent.

Section treatments. Table 2B shows that toxicant concentration in the vertically

[2]Measurement of the toxicant content has been left in terms of percent because conversion to pentachlorophenol equivalencies was not necessary for the statistical analysis. No standard specific gravity determinations were made; however, the average post weighed 16.17 pounds and contained 0.52 cu. ft. of wood at 15 percent moisture content. Thus, the average density of the air-dried wood was approximately 32 pounds per cu. ft.

TABLE 3. Average concentration of pentachlorophenol at various locations in shortleaf pine posts treated in vertical and horizontal positions.

Radial depth, inch		Pentachlorophenol concentration, percent Distance from top of post to point of analysis, feet[1] 0.75 Section A[1]	3.50 Section B[1]	6.25 Section C[1]	Av.
0.28	(1) V[2]	.627	.821	.849	.766
	H	.703	.684	.714	.700
0.59	(2) V	.529	.745	.809	.694
	H	.630	.617	.599	.615
0.91	(3) V	.353	.669	.770	.605
	H	.493	.490	.469	.484
Average	V	.509	.745	.809	.690
	H	.612	.597	.594	.601

[1]Measured to center of six-inch section.
[2]V, vertical position during treatment; H, horizontal position during treatment.

treated posts increased from 0.509 percent (Section A) to 0.809 percent (Section C) as the distance from the top of the post to center of the section increased from 0.75 to 6.25 feet. The toxicant concentration for the horizontal posts, however, showed a slight decrease from top to bottom, from 0.612 to 0.594 percent. These results also are shown in Fig. 2, the average regression for horizontally treated posts being almost a straight line with very small slope, but a steeply rising line for the vertical group. A further discussion of the results is included under "Statistical Analysis."

Layer treatments. The toxicant concentration data for vertically and horizontally treated posts were not combined in our analyses for a number of reasons. Only the horizontally treated posts were arranged in the treating tank in layers, and they were in a separate tank. Any influence of pressure on toxicant concentration was measured, in vertical posts by the difference between Sections A, B, and C, because hydrostatic pressure increased as solution depth in the vertical tank increased. In the horizontal tank, hydrostatic effects were measured by differences between layers of posts. Hydrostatic pressure could have had no significant effect on toxicant concentration developing in Sections A, B, and C within a single layer of posts because the three sections of a post in any layer were treated at the same depth in the tank and hence under the same hydrostatic pressure. These results are discussed further under "Statistical Analysis."

Radial penetration. The amount of pentachlorophenol present at various radial depths in all posts decreased from 0.729 percent at a depth of 0.28 inch to 0.535 percent at the 0.91 inch depth (Fig. 3 and Table 2B).

Statistical analysis. Interactions of main effects of variation. Table 4 is an analysis of variance for data obtained in the measurement of pentachlorophenol in the vertical posts. An "approximate F" (Cochran 1951) variance ratio, has been calculated for radial sample, section of post, and posts.

The interactions "SP," section of post by post, and "RP," radial sample by posts, are shown as highly significant. Thus the changes in pentachlorophenol concentration from one radial sample or section of post to another were not the same for

TABLE 4. Analysis of variance of data obtained from analyses of pentachlorophenol in posts treated in a vertical position.

Source of variation	Degrees of freedom	Sum of squares	Mean square	Variance ratio (F)[1]
Radial sample (R)	2	0.7430	0.37152	6.71*[2]
Section of post (S)	2	2.6407	1.32034	24.00***
Posts (P)	18	1.7494	0.90719	2.53**
Interactions				
RS	4	0.1405	0.03513	4.55**
RP	36	0.7691	0.02136	2.76***
SP	36	0.7253	0.02015	2.61***
RSP	69	0.5329	0.00772	----
Total	167	7.1616		

[1]Approximate "F" for R, S, and P.
[2]*Significant at .05 level.
**Significant at .01 level.
***Significant at .001 level.

different posts. Interactions involving a response to a change in posts were significant probably because of the variable characteristics of wood.

The "RS," radial sample by section of post, interaction for the vertically treated posts was significant at the 0.01 level. Table 3 shows that toxicant concentration at any one radial depth in vertical posts increased from top to butt and decreased in any one section as radial depth increased.

Table 5, an analysis of variance for data obtained in the measurement of pentachlorophenol in horizontal posts, shows that two of the six interactions for the horizontal posts were not significant, namely, "SL," section by layer, and "RSL," radial sample by section by layer. Table 2B and Fig. 2 show the changes in toxicant concentration in sections for different layers. One should not expect to find significant differences in solution absorption and penetration of the post by the preservative, the two factors affecting toxicant concentration within a post treated in a horizontal position, when only minor differences in hydrostatic pressure exist.

"SP," section of post by post, and "RP," radial sample by posts, interactions for the horizontal posts were very highly significant. Thus the changes in pentachlorophenol concentration from one radial sample or section of post to another were not the same for different posts in the same layer. This probably reflects differences in anatomical characteristics among posts.

The "RL," radial sample by layer, interaction for the horizontal posts was highly significant. The amount of pentachlorophenol present in a radial sample was influenced by the uniformity of penetration, or the proportion of treated to untreated wood at any one depth in a post. Thus the changes in toxicant concentration at various radial depths in the post were not the same for different layers of posts, again probably because of differences in posts, as Fig. 4 shows no correlation between layer location and toxicant distribution.

The "RS," radial sample by section of post, interaction for horizontally treated posts was a significant source of variation (Table 5). This means that the differences in toxicant concentration at various radial depths were not the same for each of the three post sections. Table 3 shows

that at depths of 0.59- and 0.91-inch, the toxicant concentration decreased from top to butt. The pentachlorophenol concentration at the 0.28-inch level was greatest in the butt section, somewhat less in the top section, and least in the center section. Toxicant concentration decreased in any one section as radial depth increased.

Section and layer effect variation. "Section" of post was not a significant source of variation in the analysis of toxicant concentration in horizontally treated posts (Table 5), whereas "Section" proved a highly significant effect in the vertical treatment (Table 4). Buckman and Pera (1952)

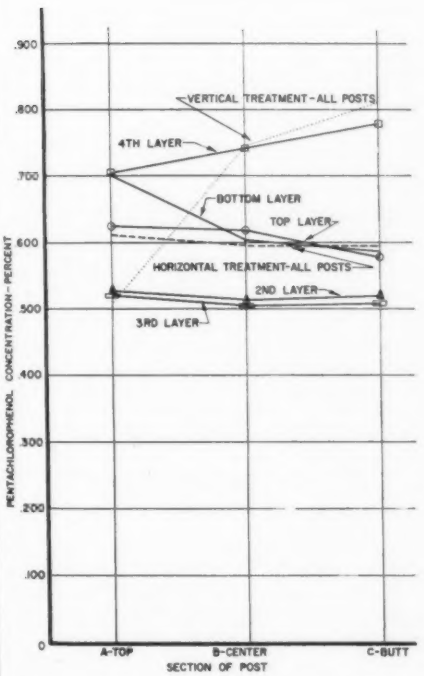

FIGURE 2. *The effect of horizontal and vertical methods of treatment on the concentration of pentachlorophenol in the top, center, and butt sections of posts.*

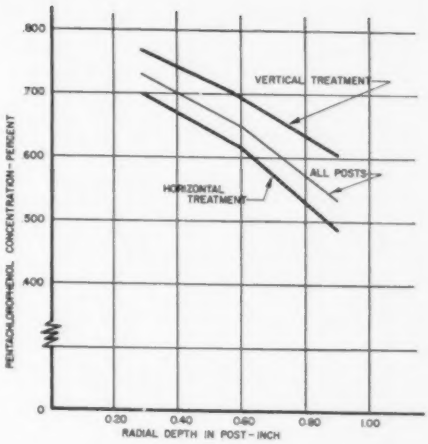

FIGURE 3. *The effect of horizontal and vertical methods of treatment on the concentration of pentachlorophenol at different radial depths in posts.*

reported that in treating southern pine posts by cold-soaking them in a horizontal position ". . . the smaller top portions absorb a greater amount of preservative and will tend to be penetrated to a greater depth than the larger butt portions." We did not determine differences in absorption and penetration for various portions of the post. Toxicant concentration, however, reflects both of these treatment criteria. Table 3 and Fig. 2 show that the top portions of the horizontal posts (Section A) had the highest average concentration of pentachlorophenol. The amount, however, was not significantly different from that found in the center and butt portions. Since the only major forces which could have influenced movement of the liquid in the posts were capillarity and hydrostatic pressure, position of the post in the tank *per se* was not a source of treatment variation. Thus, one should not expect "Section" to be a source of variation in horizontally treated posts unless capillary forces differ from

TABLE 5. Analysis of variance of data obtained from analyses of pentachlorophenol in posts treated in a horizontal position.

Source of variation	Degrees of freedom	Sum of squares	Mean square	Variance ratio (F)
Radial sample (R)	2	1.3773	0.68868	3.49*[1]
Section of post (S)	2	0.0971	0.04857	1.00 NS
Layer of posts (L)	4	1.7104	0.42761	2.17 NS
Posts (in layers) (P)	20	2.2488	0.11244	(1.75)NS
Interactions				
RS	4	0.9665	0.01662	2.82*
RL	8	0.0931	0.01163	(16.95)[2]
SL	8	0.3319	0.04149	(1.18)NS
RP	40	0.7889	0.19723	33.47***
SP	40	1.9524	0.04881	8.28***
RSL	16	0.1644	0.01028	1.74 NS
RSP	77	0.4536	0.00589	---
Total	221	9.2846		

[1]*Significant at .05 level.
**Significant at .01 level.
***Significant at .001 level.
NS—Not significant, between 0.95 and 0.05 levels.
[2]Significant at .999 level.

top to butt of the post. Since all vertically treated posts were placed in the tank butts downward, the progressive increase in toxicant concentration from top to butt (Fig. 2) is an effect of hydrostatic pressure.

The average percent of pentachlorophenol and the standard deviation for each of the five layers of horizontally treated posts are shown in Table 2B. A "Maximum F" test showed homogeneity of the variances for the five layers, justifying analysis of variance of the data.

One might expect toxicant concentrations to increase layer by layer as liquid depth and hydrostatic pressure increased. The top layer theoretically should show the lowest concentration and the bottom layer the highest amount of toxicant, with all other factors remaining constant. Table 5 and Fig. 2, however, show "layer" to be a nonsignificant source of variation. Apparently the small pressure differences during horizontal treatment were not enough to cause detectable variation in toxicant concentration among post layers.

Midpoint analysis. We have mentioned above that the average absorption of solution, average percent of sapwood penetrated, and the average percent of pentachlorophenol were greater for the vertical treatment (Table 2). Although these results are theoretically important, the post treater is more interested in knowing how well the groundline area is treated than he is in knowing how well the average post is treated.

Fig. 5 shows the percent of pentachlorophenol found at a radial depth of 0.91 inch (Sample 3) in the midpoint (B) section of posts treated in horizontal and vertical positions as a function of solution absorption. The location of the analysis was chosen because the authors believe it was deep enough to provide a reliable indication of service life as well as an indicator of how satisfactorily the posts were treated. The point also is near the groundline, the

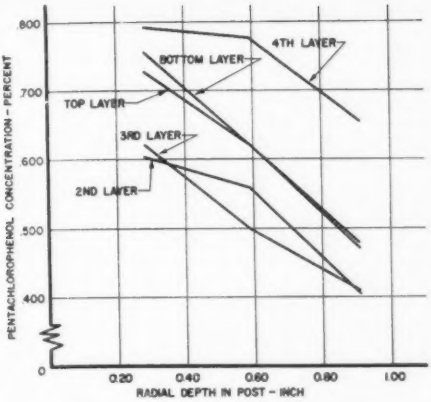

FIGURE 4. *The effect of horizontal treatment on the concentration of pentachlorophenol in various layers of posts.*

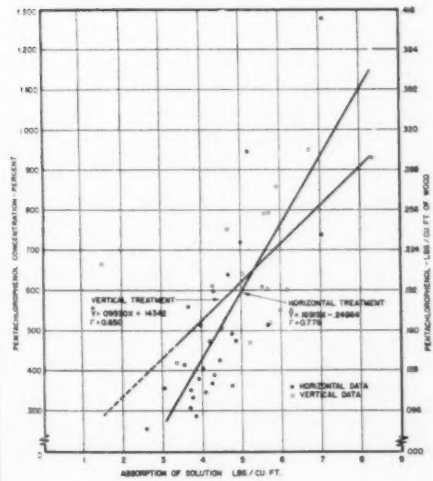

FIGURE 5. *The relation of pentachlorophenol concentration to solution absorption for horizontal and vertical methods of treatment. Based on 18 vertical and 25 horizontal observations made at a radial depth of 0.91 inch at post midpoint.*

place where post failures usually occur.

The "B-3" data were tested and the quadratic term was found to be nonsignificant for both horizontal and vertical measurements. The concentration-absorption relationships are shown by straight lines in Fig. 5. The regression equation for vertically treated posts is $Y = .09590X + .14342$. That for horizontally treated posts is $Y = .16919X - .24864$. One observation ($X = 1.48$, $Y = 0.669$) was discarded from the regression analysis for vertically treated posts.[3]

The correlation coefficient (r_h) for the horizontally treated posts was 0.776, and that for the vertically treated posts (r_v) was 0.650. When the questionable observation mentioned above was included, r_v fell to 0.483. Both values were significant at the one percent level.

The regression lines in Fig. 5 cross at approximately $Y = 0.656$, $X = 5.35$, and at higher values of X the toxicant concentration in the horizontal posts was found to be greater than that for the vertical posts for the same absorption value. One might expect the vertical regression to remain above the horizontal line for all absorption values, since hydrostatic pressure at the midpoint of the vertical posts was approximately double that for the middle (average) layer of horizontal posts. Stamm (1946) points out that penetration should increase directly as the square root of the applied pressure, although the relationship may be modified somewhat by the amount of pressure applied and the extent to which the pit-membrane pores stretch under pressure higher than atmospheric pressure. Apparently the pressure differential in our tests was not great enough to produce the expected results. Treating time was the same for the two lots of posts and so was viscosity of the treating solution at the beginning of the treating period. Stamm also indicated that depth of penetration and ab-

[3]This observation appears in Fig. 5.

sorption of solution should increase inversely as the square root of the viscosity of the treating solution. Thus, a change in temperature could have changed the viscosity of the treating solution in either treating tank. No solution temperatures were recorded during the 24-hour treating period. Air temperatures, however, ranged from 76°F. to 89°F. (average 76.5°F.). Thus any changes in viscosity of the treating solution that may have resulted from temperature changes are believed to have had an insignificant effect upon absorption and penetration. Therefore, we attribute the crossing either to experimental error or post variation, or both.

An absorption of six pounds of solution per cubic foot of wood is recommended by the AWPA as a standard treatment. Fig. 5 shows that the gross concentration of pentachlorophenol at a radial depth of 0.91 inch in the midpoint (B) section of the horizontal posts for a 6-pound treatment was higher (0.766 percent) than that for the same location in the vertically treated posts (0.718 percent). We can convert the percentages into toxicant equivalencies by multiplying them by the density of the wood, 32 pounds per cubic foot.[1] Thus the B-3 samples from horizontal posts contained 0.25 pound of pentachlorophenol[4] per cubic foot, and those for the vertically treated posts contained 0.23 pound per cubic foot.

We have no way of knowing whether the toxicant concentrations in the posts were high enough to have provided long economical service.[5] We believe, however, that the posts would serve satisfactorily, providing the toxicant was uniformly distributed. An analysis of the B-3 toxicant data showed the standard deviation for the horizontal posts to be 0.225 percent, and the vertically treated posts to be 0.159 percent, so that there was less uniformity in posts treated horizontally.

[4]Gross value; the chloride content of the reagents and wood was not determined.

Summary and Conclusions

Forty-four round, shortleaf pine fence posts were peeled, air-seasoned, and cold-soaked for 24 hours in a fuel-oil solution of pentachlorophenol. Twenty-five of the posts were arranged in five layers of five posts per layer and treated in a horizontal position. The remainder were treated full length, butts downward, in a vertical position.

The posts were measured and weighed before and after treatment. Increment borings were taken to determine thickness of sapwood and depth of preservative solution penetration.

Cylindrical sections six inches long were cut from the top, midpoint, and butt portions of each post. Each section was analyzed for pentachlorophenol content at radial depths of 0.28-, 0.59-, and 0.91-inch. A total of 390 toxicant concentration measurements were made.

The average solution absorption for all posts was 4.73 pounds per cubic foot. The vertically treated posts absorbed an average of 5.21 pounds of solution per cubic foot, whereas those treated in a horizontal position absorbed only 4.37 pounds.

Eighty-eight percent of the sapwood on the vertical posts was treated, whereas only 65 percent of the sapwood on the horizontal posts was treated.

The average gross toxicant concentration for the vertical group was 0.690 percent, and that for the horizontal posts was 0.601. Average gross toxicant concentra-

[5]AWPA Committee T-2 has reported (1952) that the concentration of dry pentachlorophenol at a radial depth of about 0.9 inch in pressure-treated southern pine poles averaged about 0.33 pound per cu. ft. of pole for two charges. The poles were believed to be treated adequately, having a net retention of pentachlorophenol solution which averaged 8.14 and 8.91 pounds per cu. ft. for two charges. The 8-pound retentions were much heavier, however, than the retentions recommended for fence posts.

tion for all posts decreased from 0.729 percent at a radial depth in the post of 0.28 inch to 0.535 percent at a depth of 0.91 inch. A similar trend in the amount of toxicant present at different radial depths in a post was found for the horizontal and vertical groups, although the drop was much greater for the horizontal treatment.

Average toxicant concentration in vertically treated posts was greatest in the butt section, somewhat less in the middle section, and least in the top section, but for the horizontally treated group it decreased slightly from top to butt. The increase in toxicant concentration in the vertical group is attributed mainly to hydrostatic pressure of the treating solution.

Treatment variations resulting from differences in treatability of individual posts proved very highly significant. The variations were attributed to the variable character of wood.

The relationship between the amount of pentachlorophenol found at a radial depth of 0.91 inch in the midpoint section of the horizontal posts and the absorption of preservative solution in pounds per cubic foot of post had a higher correlation coefficient than that for the vertical posts. Linear regression equations were calculated for both treatments.

An analysis of toxicant concentration obtained from a depth of 0.91 inch in the midpoint section of treated posts showed less uniformity in posts treated horizontally.

The authors conclude that shortleaf pine posts cold-soaked in a fuel-oil solution of pentachlorophenol in a vertical position were better treated than those treated in a horizontal position, but that post position in the treating tank *per se* had no effect on the treating results. We believe the better results secured through vertical treatment justify the use of this method.

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Prevention of Damping-off of Poplar Seedlings

BY
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DAMPING-OFF is a major disease of *Populus* seedlings. In a genetic improvement program, entire populations of valuable seedlings may be lost. The purpose of the present study was to develop means for preventing damping-off of poplar seedlings in the greenhouse. Preliminary reports have appeared (Shea and Riker, 1954, and Shea et al., 1954).

Introduction

The poplars (*Populus* spp.) have become increasingly important to the wood-using industries in the Lake States. They have various uses (Zasada, 1947). The aspen type occupies approximately 40 percent, or 19.5 million acres, of the commercial forest land in the region (Cunningham, 1950). Various factors such as poor quality, insect pests and diseases, especially Hypoxylon canker, limit productivity. However, because each species of *Populus* has certain desirable characteristics, and because the different species hybridize readily, genetic mixtures have an excellent possibility for combining many good characteristics.

To exploit the potentials of the various species, a poplar improvement program was initiated in 1938 at the University of Wisconsin in cooperation with the Wisconsin Conservation Department. Among the objectives were the production of fast-growing, disease-resistant poplars which were adapted to various conditions and which possessed desirable characteristics.

So far, among the species that root from cuttings, over 700 clones have been acquired for propagation and testing. In 1948, controlled pollinations with cut branches from elite parents were begun indoors. Although seeds were obtained in large numbers, damping-off frequently eliminated entire seedlings progenies. To overcome the limitations imposed by damping-off, this investigation was initiated.

Materials and Methods

Evaluations of the various treatments were made in three-inch flower pots. The materials tried for the control of damping-off are described in the individual experiments.

In all experiments, 100 poplar seeds (*P. tremuloides* Michx.) were sown on the surface of the germination medium in each pot and gently watered. To maintain moisture, the pots were placed in shallow pans containing about one-half inch of water and were covered with window glass. When the seedlings were approximately one-fourth inch tall, the covering was removed daily for increasing periods of time. No covering was used after 14 days.

The authors are in the Department of Plant Pathology, University of Wisconsin, Madison. Published with the approval of the Director of the Wisconsin Agricultural Experiment Station. Project supported by the University of Wisconsin and the Wisconsin Conservation Department.

TABLE 1. Average results of experiments to control damping-off of aspen seedlings.

Treatment	Rate of Application	Survival[1]
Checks		*Percent*
No treatment	.....	20
Seed treatments		
2-Chloro-4-(hydroxymercuri) phenol, 30%	excess	2
Tetrachloro-p-benzoquinone, 96%	"	4
2,3-Dichloro-1, 4-naphthoquinone, 50%	"	14
Bis(dimethylthiocarbamoyl) disulfide, 50%	"	29
Cuprous oxide (red), 96%	"	30[2]
Soil additives		
Ethylmercury phosphate, 5%	½ oz./sq. ft.	0
Ferrous sulfate, 100%	" " "	13
Bis(dimethylthiocarbamoyl) disulfide, 50%	" " "	17
Mercury phenyl cyanamide, 6%; cadmium oxide, 1%	" " "	27
Paraformaldehyde, 6%	" " "	31
Soil drenches		
Acetic acid, 1%	1 qt./sq. ft.	0
Sodium o-phenylphenoxide, 100% (1 to 800 in water)	2 " " "	25
Disodium ethylenebis (dithiocarbamate), 19% (1 to 300 in water)	" " "	35
Formaldehyde, 38% (1 to 50 in water)	" " "	86
Cuprous oxide (red), 96% (1 to 1000 in water)	" " "	89[2]
Boiling water	4 " " "	93
Other treatments		
Steaming (30 min.)	.....	68

[1]Expressed as percent of viable seeds.
[2]Chlorosis and stunting of the seedlings resulted.

The germinability of 500 seeds from each lot was determined on moistened filter paper in Petri dishes. Viability averaged over 90 percent.

Each experiment was repeated 3 or 4 times. Within each experiment, 3 replications of 3 pots each were used for each treatment. Surviving seedlings were recorded at intervals during each trial. The final results were taken approximately 30 days after sowing. Survival was expressed as the percent of germination in Petri dishes.

Experimental Results

The effects of seed treatments on the control of damping-off were tested first. The chemical names of the fungicides follow McCallan et al. (1955). Composted loam soil mixed with sand in a 3 to 1 ratio was used. The seeds were dusted by shaking them in an envelope with an excess of the protectant. The averages of the results obtained in the experiments are summarized in Table 1.

Seed treatments with either bis(dimethylthiocarbamoyl) disulfide or cuprous oxide gave somewhat greater survival than that obtained with untreated seeds. Neither treatment gave satisfactory survival, however. Furthermore, chlorosis and stunting accompanied by root burning followed cuprous oxide treatments. The other seed protectants failed to inhibit the disease. Therefore, different treatments were investi-

gated.

Three types of soil treatments, i.e., adding dry fungicides to the top 2 inches of soil, drenching the soil with fungicidal solutions or boiling water, and steaming moist soil for 30 minutes, were tried (Table 1).

When soil additives were used, ethylmercury phosphate at one-half ounce per square foot was phytotoxic. Ferrous sulfate, bis (dimethylthiocarbamoyl) disulfide, mercury phenyl cyanamide and cadmium oxide, and paraformaldehyde gave little or no disease control.

When soil drenches were tried, seedling mortality ranged from 7 to 100 percent. Although 10 days had elapsed between drenching and seeding, no seedlings survived the acetic acid treatment. Satisfactory disease control was not obtained either with sodium o-phenylphenoxide or with disodium ethylenebis(dithiocarbamate). Red cuprous oxide drenches greatly reduced damping-off, but chlorosis, stunting, and root damage occurred. Excellent disease control with no evidence of phytotoxicity was obtained when formaldehyde drenches were applied to the soil 10 days prior to seeding. After 30 days, seedlings in the formaldehyde treated soil often were 1 to 1.5 inches taller than other aspens of the same age. Soil drenches with boiling water proved to be equally effective.

Steaming potted soil for 30 minutes gave some reduction in damping-off. Disease losses, however, varied widely both within replications and among experiments. As a rule, seedlings became infected somewhat later in steamed soil than they did in the check pots. Plants which lived, although apparently free from fungal attack, frequently were stunted.

Although certain of the above treatments gave satisfactory damping-off control, a second problem appeared. Extensive root damage occurred when surviving seedlings were removed from the soil and were replanted with improved spacing. As a result, many seedlings died in the transplant flats. Consequently, a search was made for a germination medium which would permit successful transplanting and in which damping-off was not a problem.

The incidence of damping-off was determined, respectively, in an alkaline muck soil, woods soil, i.e., a loam soil from an oak woods near Madison, composted loam soil mixed with sand (3 to 1 ratio), beach sand, white silica sand, and Plainfield sand from an oak woods in central Wisconsin. The media were passed through widow screen. Sphagnum moss which was reported by Stoutmeyer et al. (1941, 1944) as a germination medium for delicate seeds of many other plants also was tried. With the latter, the pots were filled three-fourths full with beach sand over which a one-inch layer of finely divided sphagnum moss was placed. The moss was watered heavily and compacted by hand prior to seeding. Seedlings in the beach sand, white silica sand, Plainfield sand, and the sphagnum moss were watered with a nutrient solution at weekly intervals.

Marked differences were observed (Table 2) in the amount of damping-off in the various media. Severe damping-off appeared when seedlings were grown either in muck, woods soil, composted soil, or in beach sand. Seedlings grown in silica sand, in Plainfield sand, and in sphagnum moss were seldom affected by the disease. Ex-

TABLE 2. The incidence of damping-off of aspen seedlings grown in seven germination media.

Materials	Survival[1] percent
Muck soil	8
Woods soil	16
Composted soil	20
Beach sand	24
Silica sand	89
Sphagnum moss	90
Plainfield sand	96

[1]Results are expressed as percent of viable seeds.

amination of the plants in the former two materials, however, revealed that the rootlets had scarcely penetrated the surface of the sand. Eventually losses from air-drying precluded their use. An average of 90 percent of the aspens grown in sphagnum moss were free from damping-off. Moreover, flooding the pots with water prior to transplanting permitted easy separation and removal of the individual plants without root injury. Thus, subsequent losses in the transplant flats were minimized.

As a result of these experiments, the following method has been used since 1951 for culturing *Populus* seedlings in greenhouse flats. Flats were partially filled with sand and covered with approximately a one-half inch layer of finely divided sphagnum moss. These flats were sprinkled with water and steamed for 30 minutes to facilitate wetting the moss. Immediately after collection, seeds were sown on the surface of the sphagnum and the flats were covered with window glass. Subirrigation was not required if the flats were watered at frequent intervals. Following seed germination, the glass covering was removed for increasing periods each day. When the seedlings were 1 to 2 inches tall, they were transplanted to 2- by 2-inch spacing in flats filled with composted soil and sand mixture (3 to 1 ratio) where they remained until they were transplanted to the nursery. Hitt (1952) has reported that a similar technique using sphagnum moss and a peat-sand mixture sometimes is used in European poplar culture.

So far, using the above method, over 10,000 seedlings representing inter- and intraspecific pollinations among poplars in the sections *Leuce* Duby, *Tacamahaca* Spach, and *Aegeiros* Duby have been obtained for field evaluation.

Summary

The effects of 5 seed treatments, 5 soil additives, 6 soil drenches, soil steaming, and of 7 germination media on the prevention of damping-off of aspen seedlings in greenhouse flats were investigated.

None of the seed treatments or soil additives gave effective disease control. Likewise, steaming soil was unsatisfactory.

Soil drenches with formaldehyde or with boiling water controlled the disease. However, difficulties encountered in lifting the seedlings from soil nullified the value of these treatments.

Finely divided sphagnum moss proved to be the best medium for culturing poplar seedlings in the greenhouse. Damping-off was controlled and transplanting injuries were reduced.

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Transmitted Effect of Allyl Alcohol on Growth of Monterey Pine Seedlings

BY
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SEVERAL INVESTIGATORS have observed that aseptically-grown tree seedlings do not survive in prairie soils lacking mycorrhizal fungi (Wilde, 1954). This symbiotic relationship has been employed to evaluate the adverse effects of biocides by the following procedure. The seedlings are first raised from seed in biocide-treated forest soils which harbor mycorrhizal fungi. At the end of the growing season the seedlings are transplanted into a mycorrhiza-free prairie soil which has never supported forest vegetation. The subsequent deterioration of transplanted seedlings or a depression of their initial growth indicates the degree to which the biocide treatment suppressed the mycorrhizal organisms.

When this technique was used in a study of the biocidic effects of allyl alcohol, totally unexpected and inexplicable results were observed.

A coarse sandy soil (Plainfield series) autochthonously inoculated with *Cenococcum graniforme* was collected from a mature stand of jack pine and used as the growing medium in greenhouse trials. This soil was placed in half-gallon glazed jars and treated with various biocides, including allyl alcohol; the latter was applied at the rate of 50 gallons per acre. Two weeks later, on December 4, the soils were seeded to *Pinus radiata*, using 15 seeds per jar. All treatments were made in quadruplicate. Since the biocides were applied at low rates, the seedlings showed only small differences in growth at the end of six months.

Early in June, four average seedlings from each jar were transplanted into 2 gallon containers filled with prairie soil high in organic matter (Carrington silt loam). The transplants remained in the prairie soil for eight months, i.e. until reconstruction of the greenhouse terminated the experiment. At this time, none of the transplants, except those that were first raised in soils treated with allyl alcohol, exhibited appreciable differences in growth. The latter attained elephantine development (Fig. 1). A comparison of the dry matter production is given in Table 1.

During his many years of greenhouse and nursery experience, the senior author has had several opportunities to observe the stimulating "transmitted" effect of various soil treatments, i.e., an effect which becomes evident only after the stock is transplanted into a different soil. However, in no instance did the difference in growth

The authors are respectively Professor of Soils, University of Wisconsin; Assistant Professor of Soils, Yale University; and Research Associate, University of Wisconsin. Contribution from the Soils Department, Wisconsin Agricultural Experiment Station, Madison, Wis., in cooperation with the State Conservation Department. Publication approved by the Director of the Wisconsin Agricultural Experiment Station.

TABLE 1. Transmitted effect of allyl alcohol on the growth of Monterey pine seedlings (oven-dry weights)

Treatment of sandy soil harboring mycorrhizal fungi	Control	Thiosan 120 lbs/A	Chlordane 10 lbs/A	Allyl alcohol 50 gal/A
Weight of average seedling after 6 months growth in sand cultures, g.	.152	.144	.167	.154
Weight of average transplant after 8 months growth in prairie soil, g.	1.320	1.181	1.232	9.114

of plants approach the magnitude observed in this study.

There may be several explanations for the unprecedented development of *Pinus radiata*, but all of them are highly speculative. A supposition that the presence of allyl alcohol caused doubling of chromosomes is hardly valid because a change of this kind is uncommon in coniferous seedlings. According to evidence obtained recently by the use of radio-carbon (Kursanov, as reported by Snell, 1955), the photosynthetic production of carbohydrates is, under certain conditions, supplemented by the direct utilization of soil carbon. The assimiliation of carbon dioxide by roots of tree seedlings endowed with mycorrhizae was also claimed by Falck and Falck (1954). It may be possible that the allyl alcohol treatment led to the alteration of root systems which permitted utilization of nutrients locked in organic compounds of the prairie soils. If this alteration was sponsored by certain rhizospheric organisms, such organisms may not be identical with mycorrhizae-forming fungi because the root systems of the seedlings exhibited only sparse development of mycotrophic organs.

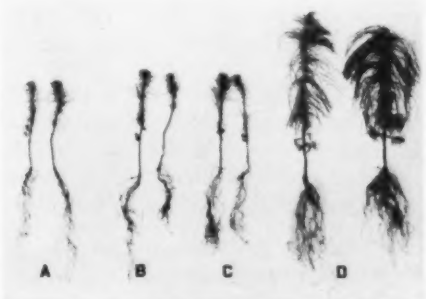

FIGURE 1. *The growth of 8-month-old Monterey pine transplants in Carrington silt loam prairie soil. Prior to transplanting, the seedlings were raised for 6 months in mycorrhiza-inoculated sandy soil either untreated (A), or treated as follows: (B) thiosan, 120 lbs./A; (C) chlordane, 10 lbs/A; (D) allyl alcohol, 50 gallons/A.*

From the standpoint of nursery stock production, this experience suggests two possibilities of diametrically opposed nature: the welcome artificial increase of the growth potential of plants, and the highly undesirable production of succulent seedlings lacking resistance to adverse climatic conditions and parasitic organisms. A crude drought-resistance test indicated that the over-developed stock from allyl alcohol cultures are highly vulnerable to drought.

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Windthrow Around Staggered Settings in Old-growth Douglas-fir

BY
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IN THE PAST DECADE, the patch-wise pattern of clear cutting known as the staggered-setting system has gained wide acceptance in the Douglas-fir forest of the Pacific Northwest. Several advantages and a few disadvantages are claimed for this cutting method in comparison with continuous clear cutting (Aufderheide, 1949). One major disadvantage of the staggered-setting system has proved to be windthrow of trees along the margins of the clear-cut units. In some areas, the damage has seriously depleted many of the settings reserved for later cutting, forcing changes in cutting plans and creating administrative problems.

This study has attempted to determine the relative importance of some of the factors which influence windthrow around clear-cut settings in the Cascade Range.

Wind Behavior in Mountains And Forests

There is a substantial literature on the behavior of wind in mountains and forests. Certain observations can be drawn from this literature which help to explain wind damage on the study area. These observations should also help forest managers in locating windfirm cutting boundaries.

1. Wind damage is often heavy on ridgetops and upper slopes. There are several reasons for the heavier damage. High ridges protrude above the general level of the terrain and are exposed to the higher wind speeds of the free air. In addition, a ridge which protrudes upward into the wind stream forms an obstruction causing vertical convergence of streamlines. As free air passes over an obstruction such as a ridge, it moves at greater speed (French, 1951). Wind damage consequently occurs in the vicinity of the crest (Smith, 1946).

Heavy wind damage in forests on ridgetops and upper slopes has been reported from many places, including the Oregon Coast Range (Ruth and Yoder, 1953); from Colorado (Alexander, 1954); from eastern Oregon by Smith and Weitknecht;[1] and from New England (Brooks, 1939).

2. If a ridge or mountain is shaped so that wind can pass around as well as over it, wind speeds will be accelerated on the shoulders of the mountain. With a west wind, for example, accelerated wind speeds

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[1]Smith, Kan., and R. H. Weitknecht. 1915. Windfall damage on cut-over areas Whitman National Forest. U. S. For. Serv., Pacif. Nthwest, For. Range Exp. Sta. Unpub. ms.

will be found on the north and south shoulders of a mountain that projects above the surrounding terrain (Smith, 1946, citing Brooks).

3. Downslope winds can cause extensive blowdown on lee slopes of mountains and ridges during severe windstorms. With winds up to 40 or 50 m.p.h., lee flow (streamlines closely following the lee slope) is most likely to develop where the lee slope is relatively smooth and the steepness does not exceed 30–35 percent (Manley, 1945). With higher speeds, however, winds evidently follow down lee slopes as great as 70 percent (Sokolowski, 1934; Ruth and Yoder, 1953).

Lee flow may develop when wind flowing across a mountain range reaches a speed of 29 m.p.h. or more at mountaintop level. Lee flow and associated wind effects are strongest with a flow of wind across and at right angles to mountain barriers, but wind direction can vary up to 50 degrees from the right angle and still cause similar effects. Any mountain range 300 feet high or higher can cause lee flow (Jenkins, 1952).

Lee flow can vary greatly in magnitude. It may be a large-scale phenomenon such as the foehn winds which develop when an air mass moves across a large mountain range (Podhorskey, 1927; Jenkins, 1952). Or it may cover a smaller area when the air mass moves across small mountains (Manley, 1945). And finally, it may be a very localized effect where a wind current within the air mass blows across a minor ridge and follows down the lee slope (Ruth and Yoder, 1953).

4. Wind is funneled through gaps and saddles in main ridges. Wind speeds are increased as a result of both the vertical and the lateral constriction of the air channel. Heavy damage may occur in and beyond the gaps and saddles (Brooks, 1939; Ruth and Yoder, 1953).

5. Wind speeds are accelerated by narrowing valleys that constrict the wind channel. Weidman (1920) observed this effect in eastern Oregon. Wind entering a wide basin in the upper end of a valley flowed down its length and spewed out through the comparatively narrow channel at the lower end. Heavy concentrations of windfall were found at the mouths of two valleys where this occurred.

6. Swiftly moving gusts of wind usually flow over the canopy of a well-stocked, even-aged coniferous forest. They rarely penetrate into the stand except where openings occur in the canopy. Inside the forest, wind speeds are much lower than in the free air above (Fons, 1940; Geiger, 1950).

7. Forest borders and cutting edges can deflect wind as much as 90 degrees, causing increased velocities where the deflected currents join others. The highest wind speeds in a cutting are often found on the leeward[2] side along the edge of the stand which deflects and guides the wind (Woelfle, 1935-36; Geiger, 1950).

8. Indentations in the edge of a stand, especially V-shaped or egg-shaped openings, produce a funneling effect which increases wind speed (Curtis, 1943).

9. Trees conditioned to strong winds are more windfirm than trees that have grown in more sheltered sites. Roots of a tree exposed to the wind receive bending stimuli which cause the development of large, strong supporting roots on its leeward side. Trees in the interior of a stand offer mutual protection from the force of stormwinds. The roots of such trees do not receive the bending stimuli which would cause them to develop strong supporting roots. Cuttings in a mature stand expose these vulnerable trees to the full force of the wind, and many are windthrown before they can become adapted to the change (Fritzsche, 1933; Jensen, 1941).

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[2]Cutting boundries over which wind passed as it entered clear cuttings are designated as "windward," and boundaries over which the wind left a clear cutting are called "leeward" in this paper.

10. Windthrow is likely to be heaviest in the first few years after cutting. The most vulnerable trees are windthrown during the first heavy storms after cutting. The remaining stand grows more windfirm with passing time (Alexander, 1954; Weidman, 1920).

11. Investigators in the Pacific Northwest have found no consistent relationship between size of clearing and amount of wind damage. Worthington (1953) observed only negligible windfall around small group clear cuts in virgin old-growth Douglas-fir, although it appeared to be severe around a large clear-cut area of 130 acres. On the other hand, Ruth and Yoder (1953) found that blowdown occurred on the lee side of openings as small as one-half acre in the Sitka spruce-western hemlock-Douglas-fir type. On eight units ranging in size from 11 to 81 acres, they found no correlation between size of clear cut and amount of blowdown.

Study Area

The H. J. Andrews Experimental Forest is located on the west slope of the Cascade Range, 50 miles east of Eugene, Oregon. It occupies the 15,000 acre drainage of Lookout Creek, a tributary of Blue River which, in turn, flows into the McKenzie River. The rough, mountainous topography and the 400-year-old stand of old-growth Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) are representative of old-growth forests on the west slopes of the Cascade Range. Western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), western redcedar (*Thuja plicata* Donn), and Pacific silver fir (*Abies amabilis* (Dougl.) Forbes) are present in the stand as understory species. Western white pine (*Pinus monticola* Dougl.), noble fir (*Abies procera* Rehd.), and incense-cedar (Libocedrus decurrens Torr.) are present in small amounts. The drainage is triangular in shape and narrows to a point at its lower end, which opens to the west-southwest. A long, high ridge rises abruptly across the wide upper end of the drainage.

Windthrow was studied around the perimeters of eight units cut in a staggered-setting pattern on a north-northwest slope (Fig. 1). The units range in size from 24 to 66 acres and lie between elevations of 1,600 and 4,000 feet. Three of the units were cut in 1950, and the remaining five in 1951.

In general, the soils are deep clay loams, but localized areas of shallow soil underlain by rock are scattered throughout the drainage.

The climate and weather conditions are typical of the Oregon Cascade Range. The winters are mild and wet, the summers warm and dry. Annual precipitation averages 65 to 100 inches, mostly rain, at the elevations occupied by Douglas-fir. About 75 percent of the precipitation falls during November through April, saturating the soil during the period when violent storm winds are most common. The wet soils furnish poor anchorage for the trees.

Methods

A total of 885 windfalls containing an estimated 1.8 million board feet of timber

FIGURE 1. *Windthrow study units on the H. J. Andrews Experimental Forest. The camera was pointed approximately southeast.*

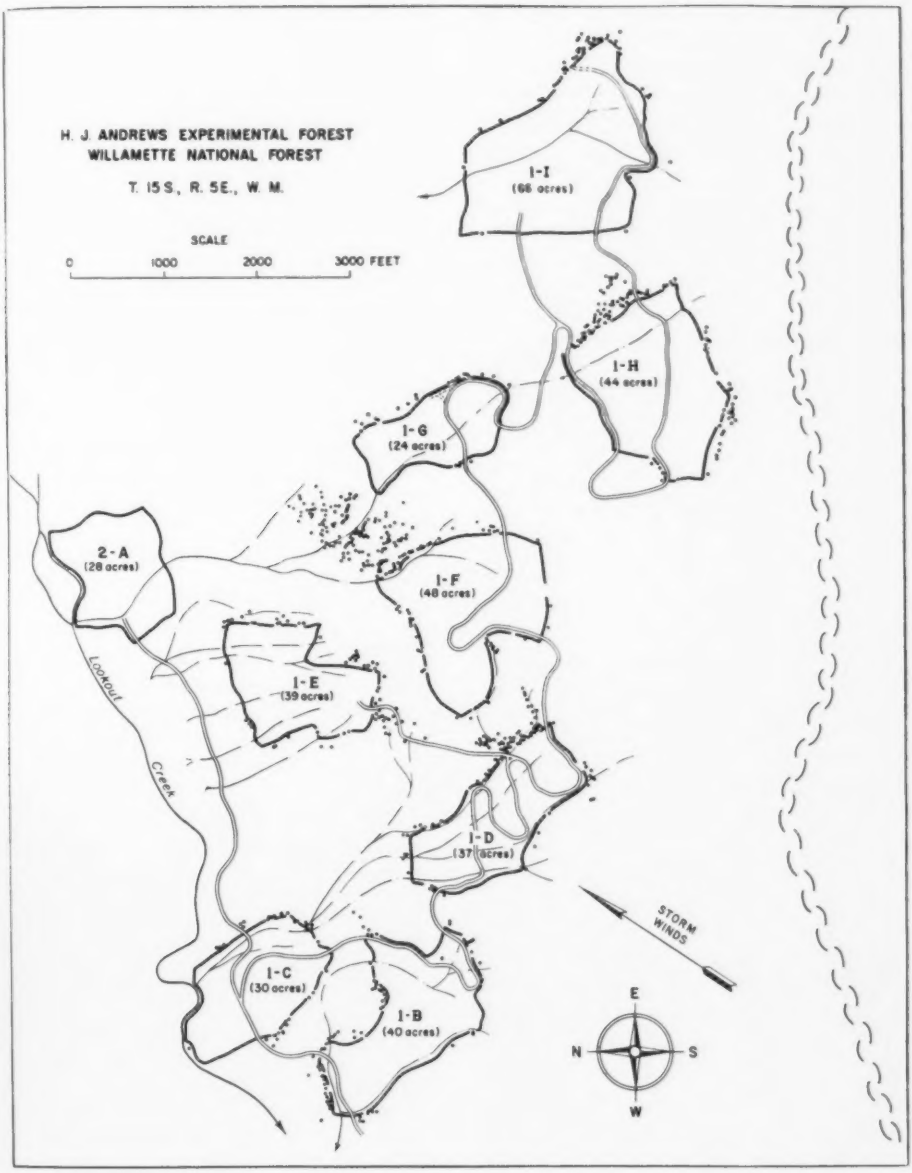

FIGURE 2. *Windfall on eight staggered settings in old-growth Douglas-fir. Locations of windthrown trees are shown by dots. Notice the main ridge south of the clear cuttings. Setting boundaries are indicated by heavy lines.*

were studied in detail. The position of each windthrown tree along 8.9 miles of cutting line was plotted on a map (Fig. 2), and the following data were recorded: Species, diameter at breast height, direction of fall, evidence of wood rots or logging injury, and soil conditions in the root holes. Finally, the position of each tree on the cutting boundary was classified according to topographic location and the distance from the cutting edge.

Wind Behavior in the Study Area

Approximately 90 percent of the windthrown trees were blown down by winds from the southwest quadrant (Fig. 3). Most of the damaging winds in western Oregon accompany southwest storms which sweep in from the Pacific Ocean during the winter. Sixty percent of the trees on the study area were felled by the violent storm of December 4, 1951, which blew down almost 5 billion board feet of timber in the Cascade Range in Oregon (Greeley *et al.*, 1953). Other southwest storms accounted for about 30 percent, and most of the remaining 10 percent were felled by east winds which occasionally reach damaging speeds.

Patterns of windfall (Fig. 2) showed that windflow on the study area was in accordance with many of the observations of wind behavior described in the literature. Windfall was light around units in topographically sheltered locations, notably units B, C, and E, G, and I. It was heavy around middle and upper slope units that were in dangerous locations according to the observations listed earlier.

Heavy and definite patterns of windfall around the upper clear cuts showed that strong winds occurred on the upper slopes (observation 1). Lighter and more haphazard windthrow around the units on the lower slopes suggests that stormwinds are generally less violent at the base of the mountain. However, not all the topographically sheltered locations are on the lower slopes. Very little windthrow occurred around unit G on the midde slope and around unit I on the upper slope.

Unit I. This clear cut is located on a very steep, concave slope on the lee side of the mountain. Stormwinds followed down the gentle gradient from the summit to the top end of the clear cut (observation 3) and caused a moderate amount of blowdown there. Below the road, however, the windthrow stopped. Here the wind did not closely follow the slope, apparently because it was too steep, or the change in slope was too abrupt. Hence there was very little windthrow around the largest part of this unit.

Unit B. A V-shaped indentation in the downwind cutting edge on unit B funneled wind into the reserve stand at the narrow end of the opening (observation 8). The gradual constriction of the air channel between cutting edges "A" and "B" (Figs. 4 and 5) concentrated the force of the accelerating wind against trees at the apex of the funnel. The winds blew down a lane of trees and extended the end of the funnel 300 feet into the uncut timber (point "C," Fig. 4). Indentations of this kind in exposed cutting edges are obviously dangerous.

Unit H. Of all the cutting units, unit H, located on the northwest shoulder of an abrupt rise in the main ridge over which

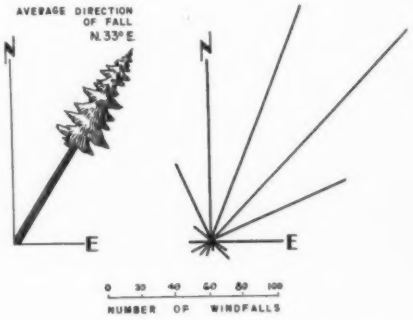

FIGURE 3. *Direction of fall for windthrown trees on the study area.*

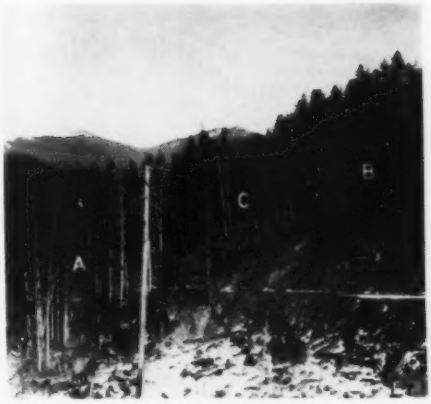

FIGURE 4. *A V-shaped indentation cut into the stand on the lee side of unit B funneled wind into the reserve stand at the point marked "C."*

the wind blows into the study area, is the most exposed topographically. The ridge and its abrupt rise represent both a vertical and a horizontal obstruction to the wind. According to observations 2 and 3, this should cause an exceptional increase in wind speed across the upwind cutting boundary. Although upwind cutting edges are protected by the uncut stand to windward and normally prove quite windfirm, heavy damage occurred in this situation. A large number of old-growth Douglas-firs on the upwind cutting edge were blown over into the unit in a uniform pattern (Fig. 2). This was the only upwind cutting boundary in the study area which was heavily damaged.

The downwind cutting edge of unit H also suffered heavy windthrow. Downslope winds on the lee side of the mountain were responsible for the damage (observation 3). The lee slope in and around the clear-cut unit is relatively smooth. The swift southwest stormwinds blow across the main ridge at an angle of about 30 degrees from a perpendicular to the ridge line. These conditions appeared favorable for development of lee flow. The stormwinds followed diagonally down the lee slope within the clear-cut area and struck the wall of timber in the northeast corner of the unit. Extensive blowdown occurred there (Fig. 2).

Unit F. The combined effects of removing a protective stand (observation 9), a downslope wind on the lee side of a ridge (observation 4), and the funneling of wind by cutting edges (observation 7) caused a large area of windthrow on unit F. Almost a half million board feet of timber were windthrown in a belt extending for a quarter-mile out of the northeast corner of the unit. (Fig. 2).

Unit F straddles a long, high secondary ridge which extends into the drainage at right angles to the path of the stormwinds (Fig. 6). In the virgin forest, the stand where the blowdown later occurred had been protected by the high forested ridge to windward (Fig. 7). Clearcutting reduced the protective height of the ridge by one-third and exposed the stand in the lee of the ridge to the full force of the stormwinds.

The north cutting boundary increased the damage by deflecting the stormwinds (observation 7) and guiding the deflected wind currents eastward along the edge of

FIGURE 5. *Wind movement through the opening as indicated by windthrown trees.*

FIGURE 6. *Storm winds blow unhindered into unit F (foreground) from the saddle on the main ridge where this picture was taken.*

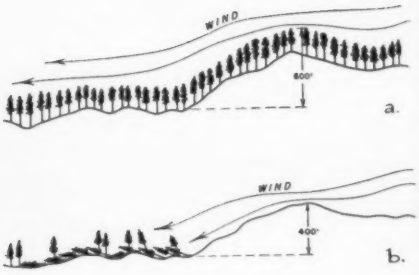

FIGURE 7. *Windflow over the ridge in unit F before cutting (a) and after cutting (b).*

the stand (Fig. 8). The deflected wind currents converged with the wind stream flowing over the crest and down the lee slope of the ridge. This further accelerated the wind speed along the north cutting edge. Where these combined winds funneled out of the unit at its northeast corner, a swath of green timber a quarter-mile long was blown down.

Penetration of windthrow into the reserve stand. Most of the windthrow around the study units occurred within 200 feet of the cutting edges. The windthrown trees were most concentrated in the first 50 feet. For each successive 50 feet away from the cutting boundary, the number diminished by about one-half (Table 1). In general, windthrow beyond the 200-foot distance was negligible and assumed a widely scattered pattern similar to that found in the virgin forest in other parts of the drainage. Average penetration of windthrow was deepest on east cutting edges where the southwest winds exerted their full force after blowing across the clear-cut area.

Blowdown beyond 200 feet from the cutting boundary occurred in only four places on the study units, all on east cutting edges. Three of the locations have already been described—funneling of wind by cutting edges in unit B, lee flow on the upper slopes in unit H, and topographic and funneling effects in unit F. The fourth location was the southeast corner of unit D, where wet soils along a creek and in a poorly drained area contributed to the heavy windthrow.

Wind escaping into or flowing out of logging road right-of-ways caused a small amount of windthrow on the edges of a few settings, but this effect seems to be relatively unimportant. The light damage was limited to about 1 chain on each side of the right-of-way on the edges of the settings. The windthrown trees were mainly of the understory species.

No attempt was made to determine amounts of windthrow along roads between the clear-cut settings. However, the windfall patterns around the study units and observation along the roads indicated that the rights-of-way were not very important in feeding the wind from clearcut to clearcut. In one place, clearing the right-of-way allowed the wind to enter a swampy area on the lee side of the road. A moderate amount of windfall occurred on this wet area.

Factors Affecting Wind Damage To the Reserve Stand

Size of clearcut. Amount of windfall showed no consistent relation to the size

TABLE 1. Penetration of windthrow into uncut stands.

Species	Number of trees windthrown according to distance from cutting edge (feet)					
	0-50	51-100	101-150	151-200	200 & over[1]	Total
Douglas-fir	98	46	31	14	88	277
Hemlock	241	112	51	27	97	528
Redcedar	25	5	6	2	12	50
Silver fir	16	6	2	....	....	24
White pine	3	....	....	....	1	4
Noble fir	....	....	1	....	....	1
Incense-cedar	....	....	1	....	....	1
All-species	383	169	92	43	198	885
Percent of all windfalls	43.3	19.1	10.4	4.8	22.4	100.0

[1]87 percent of the windthrown trees beyond the 200-foot distance from the cutting edges were in one area, extending 1,200 feet northeastward from unit F

of the cutting unit (column 4, Table 2). This agrees with observations by Ruth and Yoder (1953).

Likewise, no consistent relation was found between amount of windfall and length of perimeter of the setting (column 5, Table 2). For such a relationship to exist, the windthrown trees would have had to fall in a relatively uniform pattern around the perimeters. However, on most units, the bulk of the windfall occurred in localized patches. In every case, these concentrations were the result of soil conditions, topographic conditions, or the funneling of wind by cutting edges, rather than a result of size of setting.

Windfirmness of species. Western redcedar proved to be most windfirm, followed in order by Douglas-fir, western hemlock, and Pacific silver fir (Table 3). The three understory species as a group were one and one-fourth times more liable to windthrow than Douglas-fir. This agrees with the findings of other investigators. Boyce (1929) found western redcedar and Douglas-fir more resistant to windfall than western hemlock and silver fir. Ruth and Yoder (1953) found Douglas-fir more windfirm than western hemlock.

The low windthrow index for western redcedar applies to trees growing on the drier sites, where most of the cutting boundries were located. These trees generally were short and rapid-tapered with rather open crowns, which offer less re-

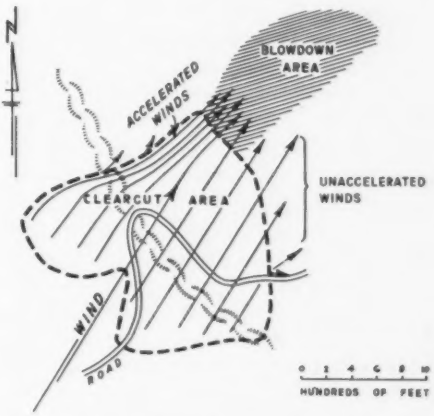

FIGURE 8. *Wind movement in unit F as indicated by the pattern of windfall.*

TABLE 2. Windfall in relation to size of setting during the first 2-year period after cutting.[1]

Unit (1)	Size (2)	Length of cutting boundary (3)	Vol. windthrown per acre clearcut (4)	Volume per chain of cutting boundary (5)	Acre equivalent[2] (6)
	Acres	*Chains*	*Bd. ft.*	*Bd. ft.*	*Acres*
G	24	68.7	3,040	44	0.65
C	30	75.0	2,390	32	0.64
D	37	87.5	5,180	59	1.28
E	39	83.4	3,450	41	1.75
B	40	100.5	4,020	40	1.40
H	44	91.6	5,950	65	2.83
F	48	97.1	15,640	161	8.04
I	66	108.9	680	6	0.64

[1]Gross volume.

[2]Number of acres in the original stand on each unit which would be equivalent to the volume windthrown around the unit. This comparison allows for differences in stand density and size of trees.

sistance to wind than the more dense crowns of western hemlock and silver fir. Curtis (1943) found that open-crowned trees were among the most resistant to windthrow. Boyce (1929) attributed the windfirmness of western redcedar on the Olympic Peninsula to its open crown, short bole, and deep root system.

In the uncut stand, hemlock and silver fir in the understory were protected from the force of storm winds by the taller Douglas-firs. Fritzsche (1933) has pointed out that root systems developed under such conditions are not adapted to withstand drastically increased wind stresses such as those which occur on the perimeters of clear-cut settings. These trees were, therefore, very susceptible to windthrow (observation 9).

All sizes of Douglas-fir seemed equally susceptible to windthrow. The number windthrown by diameter classes was in proportion to the abundance of trees of those diameter classes in the virgin stand. The larger diameter western hemlocks also proved just as susceptible to windthrow as smaller ones.

Topographic location of cutting boundary. Windfirmness of cutting boundaries on different topographic locations was compared on the basis of number of Douglas-fir windfalls per chain of cutting boundary. Only Douglas-fir was used for this comparison because they were the largest trees and contained 77 percent of the windfall volume.

Cutting edges located parallel to the contour or along roads sustained the least windthrow (Table 4). This low rate of loss was not due to topographic location but to the fact that southwest storm winds in the study area blow parallel to cutting edges on the contour. Therefore, the trees on such boundaries were not exposed to the full force of the storm winds. As road grades on the study area are usually 7 percent or less, with maximum grades of 10 percent, cutting boundaries along roads are, in effect, vary similar to those located parallel to the contour.

Cutting boundaries at right angles to the destructive winds were more windfirm when located along ridges than when located along creeks or perpendicular to the

TABLE 3. Relative susceptibility of Douglas-fir and associated species to windthrow.

Species	Composition of stand		Composition of windfalls[1]		Susceptibility ratio[2]	Windthrow index[3]
	Stems	Percent	Stems	Percent		
Douglas-fir	274	41.1	250	35.2	.856	1.0
Western hemlock	313	46.9	397	55.8	1.190	1.4
Western redcedar	68	10.2	38	5.4	.529	.6
Pacific Silver fir	12	1.8	20	2.8	1.556	1.8
Western white pine	[4] T	.....	4	.6	.....	.....
Noble fir	T	.....	1	.1	.....	.....
Incense-cedar	T	.....	1	.1	.....	.....
Totals	[5] 667	100.0	711	100.0	.....	.....

[1]Trees knocked down by others have been excluded.

[2]The susceptibility ratio (S.R.) was obtained by dividing composition of windfalls, in percent, by stand composition, in percent, for each species.

[3]Windthrow index was obtained by dividing the S.R. for each species by the S.R. for Douglas-fir.

[4]Trace species. A small number of trees of these species are present in the stand although none were encountered on the cruise plots used to determine stand composition.

[5]Trees sampled on 48 quarter-acre cruise plots to determine stand composition.

contour on smooth slopes (Table 4). Boundaries along creeks were least windfirm of all. Creek-side boundaries invariably passed through some of the wettest soils in the study area, and the wet soils induced shallow rooting and provided poor anchorage for tree roots.

Factors Affecting Windthrow of Individual Trees

The force of the wind is not the only factor which determines whether a particular tree will blow down or remain standing. Only one-third of the windthrown trees were found to have been sound trees growing on deep, well-drained soils (Table 5). One-fifth of the fallen trees were not windthrown but were knocked down by other trees. This type of damage was heaviest in the understory species; one out of every four windfalls had been knocked down. Such losses were much lower for Douglas-fir; only one out of every ten windfalls had been knocked down. The large, old-growth Douglas-firs were usually knocked down only when struck by another falling fir, while the smaller hemlocks and cedars were felled when struck by falling trees of any species.

Soil depth. Shallow soil, in which root development was restricted by rock or an impermeable layer less than 18 inches below the surface, was an important factor in windthrow of Douglas-fir on localized areas. It was exceeded in importance only by root and butt rots, which are much more widely distributed throughout the stand. Shallow soils were most often found on the points of secondary and other minor ridges but are not restricted to such locations in the Cascade Range. They are also found along rock outcroppings and in the bottoms of many of the steep canyons.

Soil drainage. Trees growing on wet, poorly drained soils were very susceptible to windthrow. Concentrations of windfall were found on several such areas. Although poorly drained soil was associated with the loss of only 6.5 percent of the windthrown Douglas-firs, it was a much more important factor in windthrow of western hemlock and western redcedar.

TABLE 4. Number of windfalls per chain of cutting boundary by species and by topographic location of cutting boundary.

Topographic location	Length of cutting boundary (chains)	Windfalls per chain							
		Douglas-fir	Western hemlock	Western redcedar	Silver fir	White pine	Noble fir	Incense cedar	All species
Along road	100.2	0.14	0.29	0.04	.....	.....	0.01	.....	0.48
Along creek	146.1	.98	2.05	.11	0.01	0.01	.....	.....	3.16
Along ridge	184.5	.27	.59	.12	.06	.02	.....	.....	1.06
Perpendicular to contour	213.0	.29	.30	.02	.02	.....	.....	.....	.63
Parallel to contour	64.9	.14	.42	.03	.11	.....	.....	0.02	.72
Outer edge of bench	4.0	.....	.....	.25	.....	.....	.....	.....	.....

A high water table may be present on some areas only during the rainy season. During the dry summer period, when many of the cutting units are laid out, these places may be difficult to recognize. Local topography is often helpful. Shallow basins on flats or benches at the base of a slope may become saturated during the rainy season. A high water table may also be present in streambanks along shallow watercourses or the streams may overflow and saturate adjacent areas.

Skunk cabbage (*Lysichitum americanum* Hulten and St. J.) is an excellent indicator of poorly drained areas (Ruth and Yoder, 1953). Root systems of windfalls are also useful. On sites with a high water table, the root systems often have a flat, tablelike appearance on the bottom. A somewhat similar root development may also occur where rock or dense clay layers restrict root development. In either case, it would not be wise to expose such areas on the edge of a clear cut.

Decay. Root rots were by far the most important factor predisposing Douglas-fir to windthrow (Table 5). Root rots were associated with the loss of 34 percent of the windthrown Douglas-firs.

Butt rots were next in importance to root rots. Almost 20 percent of the windthrown Douglas-firs had been weakened by butt rot to the point where they were either uprooted or broken off at the base.

Polyporus schweinitzii Fr., which causes red-brown butt rot, was by far the most important fungus causing windthrow of Douglas-fir. It was responsible for one-third of the root rot and all of the butt rot in windthrown Douglas-firs. An examination was made of all stumps on a strip one-third of a chain wide inside the edges of the eight study units. Although *Polyporus schweinitzii* was found in only about 18 percent of the Douglas-fir trees in the stand, this 18 percent contributed 29 percent of the windthrown Douglas-firs.

Poria weirii Murr. was second in importance. This fungus was responsible for most of the root rot in Douglas-fir. *Poria weirii* sometimes enters and causes decay in the lower portion of the bole, but it was of little importance as a butt rot in the study area. Although it was associated with almost one-fourth of the windthrown Douglas-firs, it was found as a butt rot in only about 3 percent of the 702 Douglas-

TABLE 5. Relative incidence of factors contributing to windthrow, expressed as percent[1] of windfalls, by species.

Factor	Douglas-fir	Western hemlock	Western redcedar	Silver fir	Other species	All species
			percent			
Wood rots						
Root	34.3	13.6	10.0	8.3	.....	19.7
Butt	19.5	2.7	22.0	4.2	.....	9.0
Trunk	4.7	0.6	2.0	4.2	.....	2.0
Logging injury	4.0	5.7	16.0	4.2	.....	5.8
Soil condition						
Poorly drained	6.5	14.2	16.0	.....	16.7	11.5
Shallow	7.9	7.0	16.0	20.8	33.3	8.4
Knocked down	9.8	24.8	24.0	16.7	.....	19.7
No contibuting factors	27.1	37.1	34.0	50.0	50.0	34.2

[1]Percentages are computed on the basis of the total number of stems of each species windthrown. These included 277 Douglas-firs, 528 western hemlocks, 50 western redcedars, 24 Pacific silver firs, 4 western white pines, 1 noble fir, and 1 incense-cedar. The last three species were grouped as "other species." Total windthrown trees, all species, 885. Percentages for individual species do not total 100 because windthrow of a tree was sometimes due to more than one factor.

fir stumps examined in the cutover areas. This indicates that before a *Poria weirii* infection reaches the stage where it can be detected on the stumps, it has usually caused such extensive damage to the root system that the tree is windthrown through failure of the weakened or destroyed roots.

Extensive trunk rot makes trees liable to windbreak but has little or no effect on susceptibility to windthrow. Almost 5 percent of the windthrown Douglas-firs were broken off near the lowest branches because of trunk rot (Table 5). All Douglas-firs in these severe cases of windbreak showed advanced stages of the white pocket rot caused by *Fomes pini* (Thore) Lloyd in the wood at the point of failure.

Damage as a result of windbreak is not confined to the tree in which the breakage occurs. Falling tops may knock down additional trees. Even large Douglas-firs were not immune to such damage. The results of this type of secondary damage is a needless thinning of the stand and increased exposure of the remaining trees to stormwinds.

Logging damage. Logging injuries contributed to windthrow of only a small number of trees. Most of the damage was caused by tractors cutting and tearing the roots of trees along the cutting edges while building roads and fire trails. Although the damaged trees were not invariably windthrown, the wounds provide entry points for wood-rotting fungi which can weaken the tree and cause it to be windthrown in the future.

The burning out of tree roots and butts by escaped slash fires was also classified as logging damage. This type of damage appeared particularly severe on gravelly and rocky soils. Air reaching the fire through the spaces between the rocks apparently allowed the ground fire to burn out tree roots more thoroughly than similar fires on deep loamy soils. Trees with rotten roots or butts were especially susceptible to damage by escaped slash fires. They either burned down immediately or were left in such weakened condition that they blew down afterward. Many healthy trees were burned so badly that they died within a

year or two after the fire. This resulted in an indiscriminate thinning of the edge of the stand and increased the exposure of the remaining trees to storm damage.

Conclusions and Application Of Results

Windthrow around staggered settings cannot be eliminated entirely, but it can be reduced. Success in a particular area will depend largely upon the judgment of the forester who lays out the settings. The results of this and other studies suggest several ways foresters can reduce wind damage around staggered settings in the Oregon Cascade Range.

Destructive winds in the Cascade Range usually come from the southwest, but east winds also cause appreciable windthrow. Settings should be designed for maximum protection from the southwest winds. However, in areas known to be subject to strong east winds, the cutting edges which will be exposed to the east winds should also be chosen with special care.

Windward cutting boundaries and boundaries located parallel to the direction of stormwinds generally suffered only light damage. Protection from wind damage need not be the governing factor in the selection of these boundaries. A normal amount of care in their selection should be sufficient.

Leeward cutting boundaries suffered the greatest windthrow losses (Fig. 2). Prevention of windthrow should be a major consideration in locating leeward cutting boundaries.

The relationship between windthrow and topographic location of cutting boundaries suggests a unit design for reduction of windfall on slopes with northwest or southeast exposures in the Cascades. The top and bottom boundaries of the clear cut should be located either along roads or parallel to the contour on benches. A somewhat less desirable location for the lower boundary would be along a main creek. The side boundaries should be located

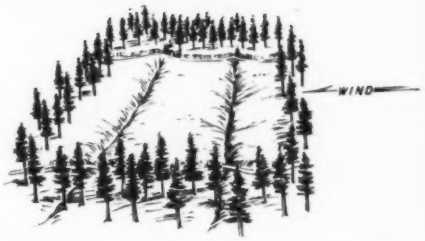

FIGURE 9. *Unit design suggested for northwest and southeast slopes in the Cascade Range.*

either on the crest or on the windward slopes near the crest of a secondary or other minor ridge (Fig. 9). Units laid out in this manner should result in a minimum of windthrow, simplify salvage of any windthrow which does occur, and eliminate the necessity for yarding salvage logs through the regenerating area. In addition, some slash burning problems are simplified (Silen, 1955).

On long, high ridges which are exposed to storm winds, cutting should start in the lee of the ridge. Clear cutting the top of a secondary ridge that obstructs the wind can indirectly cause extensive blowdown in the stand in its lee. Windthrow might be minimized by cutting successive settings "into the wind"—for example, starting two settings beyond the base of the ridge (Fig. 10). The last setting in the series should include the stand on the windward slope of the ridge. By allowing time for each clear-cut setting to restock before the next unit is cut, the new stands will decrease in height to windward, and the extent of cutting boundaries exposed to wind damage will be minimized.

Additional guides for reduction of windthrow. Following are some further suggestions that may be helpful in reduction of windthrow around staggered settings.

1. Locate cutting boundaries that are exposed to damaging winds at least 200 feet from poorly drained or shallow soils.

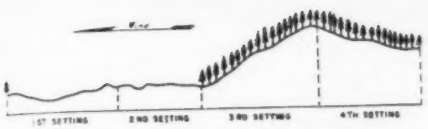

FIGURE 10. *Cutting pattern suggested for wind-exposed ridgetops.*

2. Do not locate a corner of the clearcut where the cutting edges can funnel wind into a poorly drained area.
3. Do not cut V-shaped or egg-shaped indentations in the stand on the side of a clearcut exposed to damaging winds.
4. Be particularly careful in selecting cutting boundaries on the crest and upper slopes of main ridges. Such areas are exposed to especially strong winds.
5. Where there is a choice of two locations for a cutting line and both are on equally favorable topography, locate the line through the stand composed of the more windfirm species.
6. Do not expose cutting boundaries in which either *Polyporus schweinitzii* Fr. or *Poria weirii* Murr. are abundant. Such stands are highly susceptible to windthrow, and should be removed during the early cutting cycles.
7. Trees along the cutting line that show signs of root rot, butt rot, or extensive trunk rot should be marked for removal while the unit is being logged.
8. Be particularly careful in preventing escape of slash fires into stands where root or butt rot is abundant or into stands on rocky soils.
9. Avoid damage to root systems of trees when building roads and fire trails with bulldozers. If trees are undercut or the roots badly torn, they should be removed.

Windthrow problems are complex in mountainous country. An infinite variety of windthrow situations are present. Great care will be needed in the layout of cutting units if windthrow is to be minimized. The application of the results of this study should prove helpful in selection of windfirm cutting boundaries and recognition of dangerous areas.

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German Silvicultural Systems

BY
STEPHEN H. SPURR

AN UNDERSTANDING of German silviculture is complicated by the complicated terminology by German foresters. This paper represents an effort to simplify and explain modern German usage and practice in regard to the regeneration of high forests. The basic material is drawn from the recent texts of Troup, Vanselow, Oelkers, Bauer and Dengler.

Two major impressions emerge from this study. The first is that German silviculture is not the highly systematic artificial system that we often think it is. All the major German writers examined based their silviculture upon an exhaustive study of forest ecology, and all take great pains to demonstrate how the various silvicultural systems are the product of the interaction of local biologic and economic considerations. It is fairly clear that their silviculture is definitely a "natural science." Each method was worked out on the ground to meet a given set of conditions. The classification and name-compounding came later and are in the normal German tradition.

The second impression is of the close parallel between Germany and American experience in silviculture. Rather than being alien disciplines, they are one and the same, if one makes proper allowance for the biological and economic differences between the forests of the two countries. The German foresters have complicated their silviculture with nomenclature while we have tended to over-simplify in our texts the practices which we actually employ in our forests. Actual differences between the two areas are much less than would seem to be the case from a casual examination of textbooks or a casual visit overseas.

A few notes on German silvicultural terminology are in order before one begins to examine their silvicultural systems in detail.

Among the words used as prefixes, *schirm*, *femel*, and *Blender* are used in several senses. *Schirm*, literally shelter, protection, or shade, is roughly synonymous with the English and American term *shelterwood*. It thus appears in many different terms. It may imply shelter for young growth from directly overhead only, or it may be used in a broader sense to imply shelter from the side rather than or as well as overhead.

Femel- is a prefix derived from the verb *femeln*, to select. It is synonymous with American *"selective"* in *"selective cutting,"* in that it is used to describe only operations where some trees are cut and some left, quite irrespective of whether the operation falls under the selection system or not. For instance, *künstlicher Femelschlag* is a spot clearcutting, *Femelschlagbetrieb* and *Femelschlag* refer to irregular shelterwood methods closely akin to selective logging methods in western United States, while *Femelbetrieb* is the true selection system.

Blender is a variant of *Plenter* which is in turn derived from the verb *plentern* (later *plänтern*), meaning *to select*. Neither variant is used at present except in their specific forestry meanings. The usage of *Blender* (and *Plenter*) is similar to that of *Femel* and *selective* discussed above. *Plenterbetrieb* is the selection system, but various shelterwood and other systems leading to even-aged forms also include the term in their name. The variant *Blender* has been largely used by Christof Wagner to apply to several silvicultural systems.

Several suffixes are used to designate silvicultural systems and cutting operations. A system may be designated by *-betrieb*, *-wirtschaft*, and *-stellung*. All are synonyms. *Betrieb* is the most commonly used, and generally pertains to a specific method rather than to a broad class of methods. *Verfahren*, or *method*, is also used in a similar sense.

Individual fellings or specific silvicultural methods are designated by the suffixes *-schlag* and *-hieb*. The meanings are identical.

Classification of Systems

The primary breakdown of methods is based upon the intensity of the cutting. Practically all German writers recognize (1) clear-cutting, in which no protection is given to the regeneration by the parent stand, and (2) shade or shelterwood cutting, in which such protection is given. Many writers have broken the shelterwood system into two divisions, depending upon whether the protection is given to the natural regeneration from overhead or from the side. Thus, Gayer in his "Waldbau" (1898) distinguishes between *I. Naturbesamung durch Schirmstand*, and II. *Naturbesamung durch Seitenstand*. Similarly, Vanselow (1931) emphasizes the difference between the shelterwood system (*Schirmstellung*) and the border cutting system (*Randstellung*). Dengler (1944) also recognizes shelterwood (*Schirmschlagformen*) and strip-cutting forms (*Saumschlagformen*). The difficulty with such a breakdown is that the methods actually used more frequently than not partake of the character of both types of shelterwood. It seems wise, therefore, to consider both types of protection under the single title of shelterwood.

The seed tree system is scarcely recognized as such in German silviculture. Actually, the leaving of seed trees is considered a variant of the clearcutting system that is seldom applicable in a region where the danger of windthrow is great. It is only used for Scotch pine, and then largely for the purpose of growing large standards rather than for the purpose of supplying seed (Dengler). *Einzelüberhalt* denotes single isolated standards, while *Horstweiser überhalt* denotes the leaving of groups or clumps.

The selective system, also, is not given the importance in Germany that it has in American literature. For many years, the term applied to an unregulated or economic selection that was hardly considered a system at all, or at best classified as a variant of the shelterwood system. As late as 1931, Vanselow considers various cutting methods that now would be named selection methods as types of uniform shelterwood cutting. Only since the prominence given to the *Dauerwald* concepts developed at Barenthoren, and to the *méthode du contrôle*, developed by Biolley in Switzerland has the *Plenterwald* or *Femelwald* emerged as a major type of forest characterized by a major reproduction system.

The second basis of classification common to the major German silviculturists is that of the area and shape of the cut (*schlag* or *hieb*). Within each of the major divisions discussed above, many subordinate methods can be differentiated on this basis. If the cut covers a large area or even the entire forest, this is designated by the prefix *gross*, which thus has the same connotation as the American word *uniform*. *Grosschirmschlag*, therefore may be translated as *uniform shelterwood cutting*.

More often, however, the cutting is localized in zones or areas. If these are still large enough, however, so that the effect of adjacent stands on the cutting area is negligible, the prefixes *Breit-* or *zonenweiser-* are used.

Even more commonly, however, the cutting areas are small (*Schmalkahlschlag*) so that they are affected by the adjacent standing timber. If in the form of broad strip, the term *streifen* is used; if narrow strips, the term *saum* is used; if wedge-shaped, the term *keil* is used, etc. Hole or spot cuttings are similarly differentiated, *loch* being the generic term, while *horst* applies to stands less than 1 hectare in diameter but also with a diameter of from 1 to 2 times the height of the old stand, and *gruppe* applies to smaller stands with a diameter up to the height of the old stand, etc.

Thus, the German classification of silvicultural methods can be broken down into a primary segregation based upon the intensity of cutting (clearcutting, shelterwood cutting, or selection cutting), and a secondary segregation based upon the size and shape of the cutting area. The actual cutting practices themselves often do not correspond to the above classification in every detail, so are frequently named by an elaborate compounding of the basic silvicultural terms, or are given the name of their chief exponent or locality in which they are practiced.

Clearcutting

Clearcutting in Germany is carefully differentiated into the large-area type where artificial regeneration is to be employed, and the small-area type where natural regeneration is expected from the side (*seite* or *Rand*). The former has primarily been used with spruce, more so in the past than at present, while the latter is primarily used for Scotch pine, but also to some extent for spruce. Small-area clearcuttings are indicated for the Scotch pine type because this species will not regenerate readily over the root systems of the old trees.

The width of the small-area clearcutting is determined by the seed dispersal characteristics of the species, the wind direction and the shade protection of the old stand. Birch and larch are regenerated frequently by this method, as well as the pine and spruce mentioned above. Spot clearcutting (*Löcherkahlschlag*) is sometumes employed but strips are more often clearcut. If the strips are wide, they are *Streifen* (10 to 20 meters); if narrower, they are *Säume*; and if wedge-shaped, *Keile*. The cutting ordinarily takes the form of strips, the long axes of which lie at right angles to the prevailing wind, with successive cuts being placed toward the wind. This procedure gives the maximum protection to the young growth from wind and frost.

Alternate strip cuttings are designated *Kulissenhieb*, *Springschlag*, or *Wechselschlag*, but the method is seldom employed. A checkerboard pattern of cutting is logically termed *Schachbrettschlag*.

Uniform Shelterwood

The uniform shelterwood was primarily developed by G. L. Hartig around the end of the eighteenth century. It goes by several names, chiefly *Grosschirmschlagbetrieb*, *Breitsamenschlag*, and *Dunkelschlag*.

The several cuttings are generally as recognized in the United States. The preparatory cuttings are *Vorbereitungshiebe*. The seedling cutting is *Besamungshieb*, or when the cutting is light, *Dunkelschlag*. Later cuttings designed to encourage, the established regeneration are *Lichtungshiebe*, *Nachlichtungshiebe*, or *Nachhiebe*; while the final cutting is the *Räumungshieb*, *Abtriebsschlag*, or *Endhieb*.

The method is principally used in Germany today in beech stands. The reproduction is kept under shelter for 10 to 30 years, usually about 20, before the final cutting.

In the past, the method has been used with pine in Prussia. Here, the seedling cutting was very light, and the later cuttings very heavy, turning the operation into

what amounted to a seedtree cutting. The method was largely abandoned because of heavy wind damage to the standards.

It should be mentioned that Vanselow classified the Barenthoren regeneration and several related forms with the uniform shelterwood as being similar operations, although these cuttings are today classified as being selection cuttings.

The present trend seems to be away from the uniform shelterwood in favor of concentrating cutting operations in zones or other local areas where more intensive control of the young growth is possible. Since beech has a heavy seed year only every 6-12 years, it is more difficult to plant a uniform-cut stand than a concentrated-cut stand if natural regeneration fails.

Systematic or Strip Shelterwood Cutting

The Germans are great systematizers, of course, and this is nowhere better shown than in the great number of special silvicultural systems that have been evolved and named for the regeneration of species under protection from the old stand. A few systems are quite distinct, but most seem to be closely related so that a single operation is likely to partake of the character of several systems.

In general, however, the various shelterwood cuttings in which reproduction is localized at given areas in the forest—and these cuttings are the ones predominantly practiced in the German forests—may be roughly subdivided in systematic or strip shelterwood cuttings, and irregular or group shelterwood cuttings.

In considering the systematic or strip cuttings, it should be recognized that this class contains both the German strip shelterwood (*Saumschirmschlag*) and broader strip (*Randschlag*) cuttings. The first is recognized where the old stand is thinned out in advance of the final cutting so that the reproduction is started under the old stand, while the latter occurs when the old stand is kept dense until the final cutting and the reproduction is started to the side of the old stand but yet under its protection (in contrast to strip clearcutting).

The strip shelterwood systems as a group are largely used in the Black Forest of Würtemberg and Baden for the spruce, fir and beech mixed forests, although the wedge system is also used in pine and hardwood mixtures along the Rhine and Kautz' strip shelterwood is primarily adopted for the mountainous conditions of the Harz Mountains where beech and spruce mixtures are grown.

The conventional strip shelterwood (*Saumschlagbetrieb*) is that written up in textbooks in the English language. The cuttings of strips proceed against the prevailing wind direction (that is, toward the west or southwest in South Germany) or down the slope. The strips are 20 to 30 yards wide with the total belt under regeneration, including both the portion under the thinned-out old stand and that freed by the final removal cutting being about 75 yards wide. The actual widths, of course, varies with the species and seed years, being controlled by the successful establishment of new growth rather than by rule. The method is a logical outgrowth of the trend toward localizing the uniform shelterwood system and is largely practiced on spruce and fir.

Of the many modifications of the strip systems, Wagner's *Blendersaumschlag* has attracted the most attention. Actually, this is perhaps more of a concept rather than a single method, as Wagner's main contribution was to emphasize the adverse effect of sun and drought on the establishment of the young stand, and the possibilities of orienting strips to avoid excessive exposure of the young growth. Thus, his cuttings proceed from the north to south on level ground and approximate this direction on slopes. At the same time, protection of the cutting border from the wind (which is prevalently from the west) is obtained by keeping the strips short and staggering them so that the old wood to the west protects the next cut strip to the east. Thus, in idealized form, a step-like or saw-tooth-like pattern results.

The resulting forest is even-aged along the strips, but grades from new to mature growth in the single block. It is used primarily for spruce-fir-beech mixtures.

Kautz' strip shelterwood (*Streifenschirmschlag*) is based upon the same general principles that activate Wagner's recommendations, but are specifically designed to the steep slopes of the Harz Mountains. Cuttings of the strip type are started high on the slope parallel to it, and at intervals along the slope transverse to it. The cutting then proceeded down the slope, with the material being taken out through the old wood. Small indentations are cut diagonally downhill from the original strips so that the face of the old forest is irregular and gradually retreats down hill.

The wedge system (*Schirmkeilschlag*) of Eberhard and Phillip are considered the same by most writers, but are treated as variants by Vanselow. Actually, Eberhard seems to have been the originator of the technique on its modern form and Phillip its systematizer. It is practiced in the Black Forest of Würtemberg and Baden in spruce and fir mixtures, and is distinguished by the cutting of wedges which point into the mature timber in the direction of the wind. The wedges are gradually widened as the cutting proceeds. Bauer points out that the major difference between the wedge type and strip type cutting is that the former proceeds from the inside of the stand outside, while the latter works from the outside in.

The last major strip system is the strip-and-group system, a method which combines the cutting of groups in the advance of the clearcutting with the cutting of strips. The Bavarian strip method (*bayerischer Saumfemelschlag*) is differentiated from the closely related Bavarian combined method (*bayerische kombinierte Verfaren*) in that in the former, the strips are advanced against a dense mature stand (border cutting); while in the latter, the strips are advanced against a heavily-thinned old wood (shelter-wood cutting). Both are primarily used to develop mixed stands of tolerant and intolerant species. The strip cutting progresses against the wind. In advance of it, clumps of reproduction already established are freed, while other holes are created to favor the establishment of tolerant species. These holes are frequently planted with beech in an effort to convert pure spruce and fir coniferous forest into mixed forest. As the strip cutting progresses, the old groups are absorbed by it as new groups are created in its advance. In the combined method, the regeneration zone is ordinarily wider than in the straight Bavarian strip method.

Irregular Shelterwood Systems

In contrast to the regular or strip systems are those where the shelterwood concept prevails, but the cutting is done in spots and groups, resulting in a group-wise mixture.

Two general forms are recognized. The first is that dealing with closed and rather even-aged stands known as the Bavarian shelterwood (*bayerischer Femelschlag*). This was largely the concept of Karl Heyer who advocated it against the clearcutting systems with planting of spruce then prevalent in many areas. It was developed practically in Bavaria by von Huber. In the initial cuttings, it is similar to the uniform shelterwood system, but differs in that the final cuttings are made where the natural reproduction is best established. Later, these groups are enlarged until the stand is finally removed. In the strip-and-group (combined method) modification discussed in the previous section, a modification which is more often used than the original system, the final removal is by strip cutting, after the groups have been established. The series of cuttings may take as long as 40 years to establish and free reproduction, but 20 to 30 years is the more normal period.

The Bavarian shelterwood extends over the whole forest. A systematization of it where the cutting areas are localized in space and time is known as Kubelka's shelterwood (*Femelstreifenschlag nach Kubelka*).

The second type of irregular shelterwood is the Swiss or Baden shelterwood (*badische Femelschlag*). This is closely akin to the selection cuttings practiced in the American west. The stands are more or less open and the age-structure rather uneven-aged. Reproduction is established over a 20 to 60 year period, with 40 years being the common length. Cutting is largely of the thickest trees. The system might well be termed an "economic selection" system in American terminology, and it is in fact called by one writer the "Black Forest utilization system." As with its American counterpart, its success depends in a large measure upon the skill of the forester marking the stands and the control he extends over the cutting operations.

Both irregular shelterwood systems are primarily used for spruce, fir and beech forests in south Germany and nearby countries. Both are large-area methods and contrast with the small area systematic shelterwoods discussed above. Wagner, for instance, designated them as *Blendergrosschlag* or *Blenderschlagbetrieb* (by others, *Plenterschlagbetrieb*) in contrast to his *Blendersaumschlag* or other strip operations.

The resulting forest form is intermediate between that produced by the systematic or uniform shelterwoods and the selection system. In fact, the Swiss or Baden shelterwood is used frequently as transition system is converting a forest from even-aged to uneven-aged management form.

Selection Systems

Selection system cuttings are designated either by the term *Plenterschlag* or the term *Femelschlag*. The same terms are also sometimes used to denote various shelterwood cuttings, but the *Plenterwald* and *Femelwald*, or selection forest refers to forests resulting specifically from the selection system.

The two terms seem to be synonymous today, although there has been in the past and there seems to persist more of an economic connotation to the term *Femel*, which, as in the case of Baden *Femelschlag*, refers to rather an economic shelterwood cutting of a group type.

The selection system has apparently attracted less attention in Germany than in the United States. For many years, it was considered more bad than good, being associated with "culling" and "creaming" operations. In this respect, it has been synonymous with the American "selective" cutting. In the last thirty years, however, interest in this general type of operation has revived, largely due to the impetus provided by the "*Dauerwald*" concept and a related movement in Switzerland. Actually, Dauerwald does not refer to a specific system, but merely emphasizes the benefits to be obtained by keeping a continuous forest cover on the land, and adjusting cutting operations so as to keep the soil and site in the best possible condition. The selection system, whether of the individual tree or group type, frequently results, — but so also may various shelterwood systems. Where originally practiced at Barenthoren, the *Dauerwald* takes the form of a long-reproduction-cycle group-shelterwood system.

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Material such as equations that exceed 42 spaces on the typewriter cannot be carried in a single line. Such material should either be set so that it can be broken into two or more lines, or should be presented in tabular form.

Tables

Each table should be typewritten on a separate sheet, given a title at the top, and should be numbered consecutively. Even if only one table is submitted, it should be designated Table 1.

Footnotes used in tables should be designated by numerals, never by asterisks or other typographical symbols. These footnotes should be typewritten as part of the table.

Illustrations and Figures

An illustration — whether a photograph, a line drawing, a map, or a graph — is designated as a figure. A caption should be submitted for each illustration, but the caption should be typewritten on a separate sheet.

All figures should be numbered consecutively. If only one is submitted it should be designated Figure 1. On the margin or back of each illustration should be written lightly in soft pencil the number of the figure, the name of the author, and an abbreviated title.

Photographs should be sharp and clear, printed on glossy paper. They should not be smaller than 4 by 5 inches. Sizes 5 by 7 inches and 8 by 10 inches are preferable. Photographs should never be rolled or bent. Care should be taken in fastening photographs with paper clips which often make indentations that show up in reproduction.

Drawings, maps, charts, and graphs are reproduced as line engravings. They should be at least twice as large as they are to appear when reproduced, and should be drawn in india ink on heavy white paper, or tracing cloth.

Footnotes

To indicate a footnote, place a superior figure after the word that refers to the note. Consecutive numerals should be used, never asterisks. Separate the footnote from the text by running a line about one inch inward from the left margin of the type.

Use footnotes to give credit to unpublished material and communications. If only a few references to literature are made (less than one per 1000 words), complete literature citations may be given in footnotes rather than in a separate listing.

Literature Cited

In FOREST SCIENCE practice, references to literature citations are designated by the author's name and year of publication inserted in parentheses at the appropriate place in the text. If there are more than two authors, list only the senior author's name in the text with the abbreviation *et al.* Example: (Smith *et al.*, 1954). Only published references should be given in *Literature Cited*. Periodical abbreviations should follow *Guide to the use of Forestry Abstracts*, Commonwealth Forestry Bureau, Oxford, England, 1950.

Nomenclature and Terminology

When a species is first mentioned in a paper its common name may be immediately followed by its italicized scientific name in parentheses, but this latter name need not be repeated.

As the authority for the exact spelling of tree names, FOREST SCIENCE follows *Check List of Native and Naturalized Trees of the United States (including Alaska)*, Agriculture Handbook 41, Forest Service, U. S. Dept. Agric., Washington, D. C., 1953.

For the spelling of other plant names, contributors should follow *Standardized Plant Names*, 2d Edition, J. Horace McFarland Company, Harrisburg, Pa. 1942.

Technical usage in forestry and allied fields follows *Forestry Terminology*, 2d Edition, Society of American Foresters, Washington 6, D. C. 1950.

There are many style manuals available for the guidance of writers. One of the best is the *Style Manual* of the U. S. Government Printing Office, Washington 25, D. C. 1953.

Webster's *New International Dictionary* is the accepted authority for general spelling.